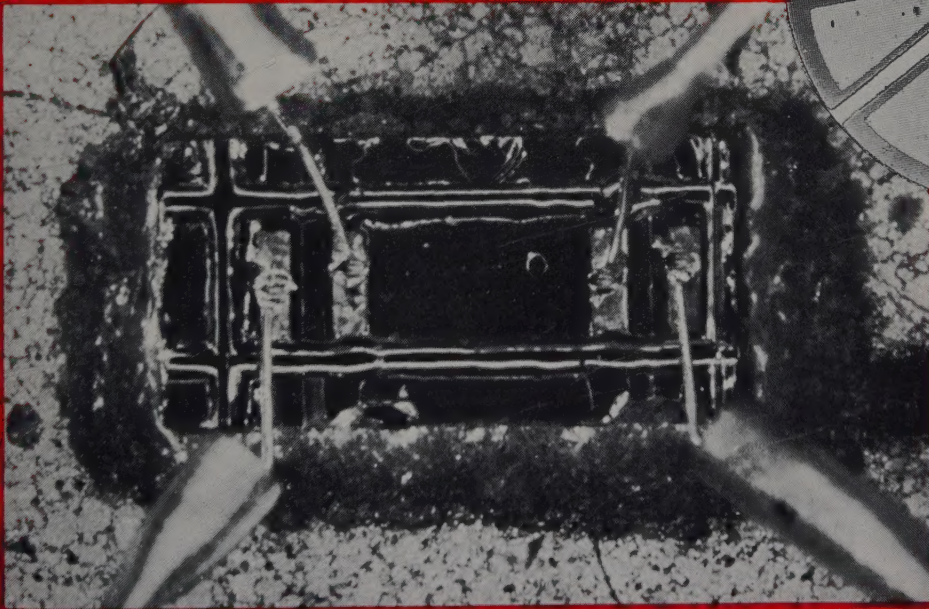


SEMICONDUCTOR PRODUCTS

ping Transistor Element



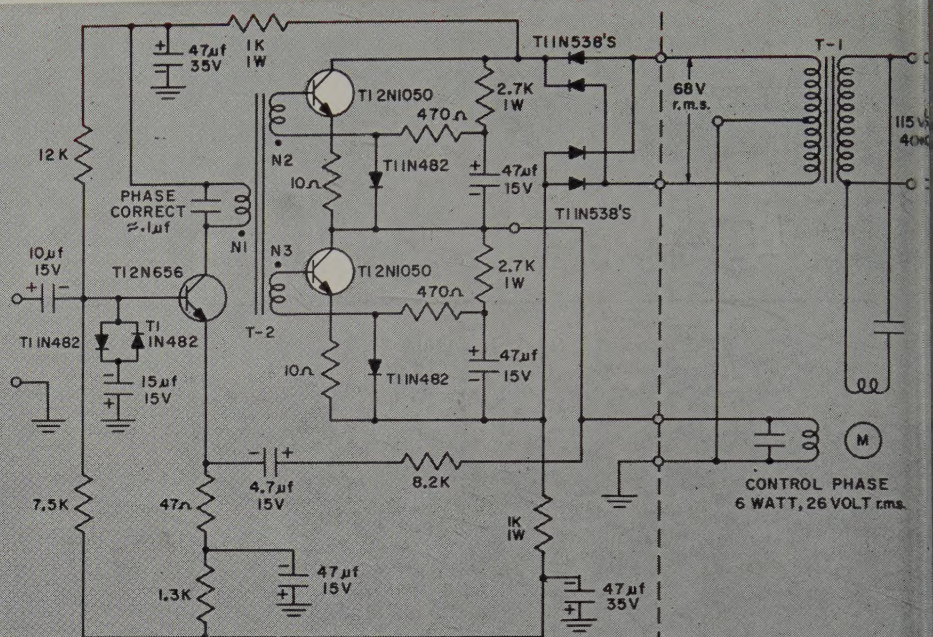
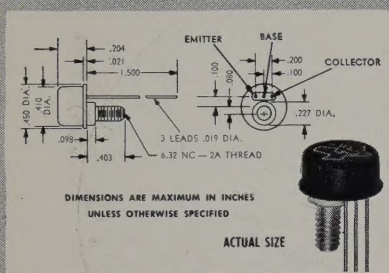
Crystal Controlled High Frequency Transistor Oscillators
• **Resistivity Measuring Techniques in Semiconductors** •
Alloying with Controlled Spreading in Silicon Transistors

How to get 55% over-all efficiency in transistorized 6-watt servo amplifier

HIGH-EFFICIENCY SERVO CIRCUIT REQUIRES ...

- no output transformer
- no center-tap motor winding

Higher over-all efficiency than in a conventional Class-B push-pull amplifier is achieved in this servo by use of unfiltered rectified a-c for current supply voltage—with resulting reduction in size, weight and power supply requirements. This higher efficiency means greater transistor reliability, smaller heat sink and/or higher allowable ambient temperatures. Output will remain sinusoidal when amplifier is overdriven.



TRANSFORMERS

T-1 400 cps, 12-watt power transformer step-down 115 volt to 68 volt c.t.

T-2 400 cps, 65-mw driver transformer. Turns ratio N1: N2: N3=2: 1: 1
Primary Current = 10 ma d-c. Primary Inductance = 1.5 hy.

...with TI 2N1050 N-P-N silicon transistors

Exclusive TI 2N1047 intermediate-power series now gives you maximum design flexibility plus high efficiency... all in a miniature package!

Consider the design flexibility made possible by the exclusive features of this series... 40 watts dissipation at 25°C case temperature... unique stud mounting for maximum thermal efficiency... 80- and 120-volt

BV_{CEX} ... 15-ohm R_{CS} ... -65°C to +200°C operating and storage range... choice of beta spreads.

Apply TI's guaranteed specs to your design situation today. This use-proved series is available off-the-shelf—at factory prices—in 1-999 quantities from your nearby authorized TI distributor, and in production quantities from your TI sales office.



Write on your company letterhead for illustrated TI APPLICATION NOTES on the transistorized servo amplifier.

PARAMETER	TEST CONDITIONS	2N1047	2N1048	2N1049	2N1050	units
		min. max.	min. max.	min. max.	min. max.	
BV_{CEX} Breakdown Voltage	$I_C = 250 \mu a$ $V_{BE} = -1.5V$	80	120	80	120	V
BV_{EBO} Breakdown Voltage	$I_E = 250 \mu a$ $I_C = 0$	10	10	10	10	V
I_{CBO} Collector Cutoff Current	$V_{CB} = 30V$ $I_E = 0$	15	15	15	15	μa
h_{FE} Current Transfer Ratio †	$V_{CE} = 10V$ $I_C = 200ma$	12 36	12 36	30 90	30 90	—
h_{IE} Input Impedance †	$V_{CE} = 10V$ $I_B = 8ma$	500	500	500	500	ohm
R_{CS} Saturation Resistance †	$I_C = 200 ma$ $I_B = 40ma$	15	15	15	15	ohm
V_{BE} Base Voltage †	$V_{CE} = 15V$ $I_C = 500ma$	10	10	10	10	V

†Semiautomatic testing is facilitated by using pulse techniques to measure these parameters. A 300-microsecond pulse (approximately 2% duty cycle) is utilized. Thus, the unit can be tested under maximum current conditions without a significant increase in junction temperature, even though no heat sink is used. The parameter values obtained in this manner are particularly pertinent for switching circuit design and, in general, indicate the true capabilities of the device.

germanium and silicon transistors
silicon diodes and rectifiers
TAN-Ticap solid tantalum capacitors
precision carbon film resistors
sensitive silicon resistors

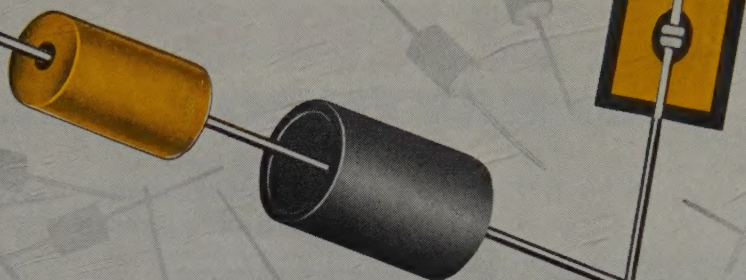
TEXAS



INSTRUMENTS
INCORPORATED
SEMICONDUCTOR-COMPONENTS DIVISION
13500 N. CENTRAL EXPRESSWAY
POST OFFICE BOX 312 • DALLAS, TEXAS

Circle No. 1 on Reader Service Card

NOW - INCREASE DIODE YIELD BY UP TO 47%



AND REDUCE UNIT COSTS WITH EPOXY E-PAK SYSTEM!

Now, Epoxy Products brings the mass production economy of the famous E-Pak system* to diode encapsulation! It works like this: the diode is inserted into a preformed yellow epoxy E-Form pellet . . . both pellet and diode are then placed in a molded epoxy case . . . heat is applied, the pellet melts, cures, seals the unit completely. It's a quick, efficient operation that requires no expensive fixturing, yet meets all applicable Mil-Specs (including MIL Std. 202-A).

This system eliminates glass to metal seals and the accompanying disadvantages of glass

cracking, and weld contamination. Heat dissipation is exceptional.

These rugged epoxy packages are homogeneous and resistant to 95% relative humidity for 1,000 hours. They can be cycled from -55°C to $+200^{\circ}\text{C}$. The yellow pellet provides immediate cathode identification and quick visibility.

If you encapsulate diodes, **every other method is now obsolete!** Write today for complete information and samples. Inquire, too, about the applications of E-Pak system to other semiconductor devices.

* Patents applied for.

EPOXY

A DIVISION OF JOSEPH WALDMAN & SONS
PRODUCTS, INC.
137 Coit Street, Irvington, New Jersey
ESsex 5-6000

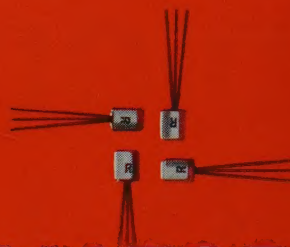
Circle No. 4 on Reader Service Card

TELEPHONE



YOU

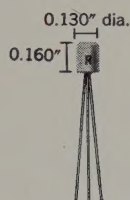
**can get the most in your space . . .
when you use**



submin TRANSISTORS

SUBMIN PNP GERMANIUM

TRANSISTORS
of RAYTHEON RELIABILITY



- a complete line
- proved performance — over 1½ million in use
- new, attractive prices

AVAILABLE FROM STOCK in large production quantities



**COMPUTER
TRANSISTORS**

Temperature Range
—65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V _{CE} max. volts	f _{αb} ave. Mc	H _{FE1} ave. I _B = 1 ma V _{CE} = -0.25V	H _{FE2} ave. I _B = 10 ma V _{CE} = -0.35V	Rise Times max. μsec
CK4	2N404	-24	12	30	—	—
CK25	2N425	-20	4	30	18	1.0
CK26	2N426	-18	6	40	24	0.55
CK27	2N427	-15	11	55	30	0.44
CK28	2N428	-12	17	80	40	0.33

*I_C = 50 ma; I_{B1} = 5 ma; R_L = 200 Ω; I_{B2} = 5 ma; Grounded Emitter Circuit



**GENERAL PURPOSE
AUDIO**

TRANSISTORS

Temperature Range
—65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V _{CE} max. volts	Beta ave. small signal	Power Gain Class A ave. db	I _{CO} ave. μa	Noise Factor ave. db
CK22	2N422	-20	90	40	6	6 max
CK64	2N464	-40	22	40	6	12
CK65	2N465	-30	45	42	6	12
CK66	2N466	-20	90	44	6	12
CK67	2N467	-15	180	45	6	12



**GENERAL PURPOSE
RADIO FREQUENCY**

TRANSISTORS

Temperature Range
—65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V _{CE} max. volts	f _{αb} ave. Mc	Beta ave.	c _{ob} ave. μμf	r _b ^{''} ave. ohms
CK13	2N413	-18	2.5	25	12	70
CK14	2N414	-15	6	40	12	80
CK16	2N416	-12	10	60	12	90
CK17	2N417	-10	20	80	12	100

Dissipation Coefficients for all submin types: in air, 0.75°C/mW; infinite sink, 0.35°C/mW



SEMICONDUCTOR DIVISION
RAYTHEON COMPANY

SILICON AND GERMANIUM DIODES AND TRANSISTORS • SILICON RECTIFIERS • CIRCUIT-PAKs

New York, Plaza 9-3900 • Boston, Hillcrest 4-6700 • Chicago, National 5-4000 • Los Angeles, Normandie 5-4221 • Orlando, Garden 3-155
Baltimore, Southfield 1-1237 • Cleveland, Winton 1-7716 • Kansas City, Plaza 3-5330 • San Francisco, Flerside 1-7711
Government Relations: 1000 16th Street, N. W., Washington, D. C. — METropolitan 8-5205

Circle No. 5 on Reader Service Card

SEMICONDUCTOR PRODUCTS • SEPTEMBER 1959

SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

September 1959 Vol. 2 No. 9

EDITOR

Samuel L. Marshall

ASSOCIATE EDITOR

Oscar Fisch

ASSISTANT EDITOR

Selma Uslaner

ADVISORY EDITORS

Dr. John Dropkin

Dr. Lucio M. Vallese

S. L. Levy

Hugh R. Lowry

CONTRIBUTING EDITORS

Henry E. Marrows

Stephen E. Lipsky

BUSINESS STAFF

Chas. W. Gardner, Jr.,
Production Manager

H. Turok, Controller

ART DIRECTOR

David Fish

ASS'T. ART DIRECTOR

Robert E. Jordan

ADVERTISING SALES

EAST & MIDWEST

Richard A. Cowan,
Jack N. Schneider,
300 West 43rd Street,
New York 36, N. Y.
JUdson 2-4460

WEST COAST

Ted E. Schell,
2700 West 3rd Street,
Los Angeles 57, Calif.
DUnkirk 2-4889

Charles W. Hoefer,
1664 Emerson Street,
Palo Alto, Calif.
DAvenport 4-2661

CIRCULATION

Harold Weisner

Circulation Director

Clinton Ide

Circ. Mgr.

Rose Mercurio

Ass't Circulation Mgr.

Editorial	9
Applications Engineering Digests	14
Crystal Controlled High Frequency Transistor Oscillators, by W. F. Chow	21
Resistivity Measuring Techniques In Semiconductors, by H. Gunther Rudenberg	28
Alloying With Controlled Spreading in Silicon Transistors, Part II, by J. Roschen, T. J. Miles, and C. G. Thornton	35
Semiconductor and Solid State Bibliography	40
Diode Charts (Cont. from August)	43
Patent Review	44
Characteristics Charts of New Transistors	45
Departments	
Book Reviews	38
New Products	51
Industry News	58
Market News	60
Personnel Notes	63
Advertisers' Index	64

Front Cover

"Stepping transistor element" developed at Bell Telephone Laboratories, mounted on a gold-plated Kovar header, is shown magnified about 50 times actual size. It may be used as a basic stage in constructing certain logic circuits of a digital computer. Leads are thermocompression bonded to gold-silver alloy contacts. Top view of stepping transistor structure (shown as insert) is fabricated on a single piece of silicon by oxide masking diffusion techniques. Actual diameter of the device is 40-thousandths of an inch. Light and dark areas show the different electrically-active regions of the stepping transistor structure. Lead wires are attached to the pie-shaped areas.

SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp. Executive and Editorial Offices, 300 West 43rd Street, New York 36, N. Y. Telephone: JUdson 2-4460 Subscription price: \$6.00 for 12 issues in the United States, U. S. Possessions, APO, FPO, Canada and Mexico, \$8.00 for 12 issues. All others: 12 issues \$10.00. Single Copy 75c. Accepted as controlled circulation publication at Bristol, Conn. Copyright 1959 by Cowan Publishing Corp.

POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS,
300 West 43rd STREET, NEW YORK 36, N. Y.

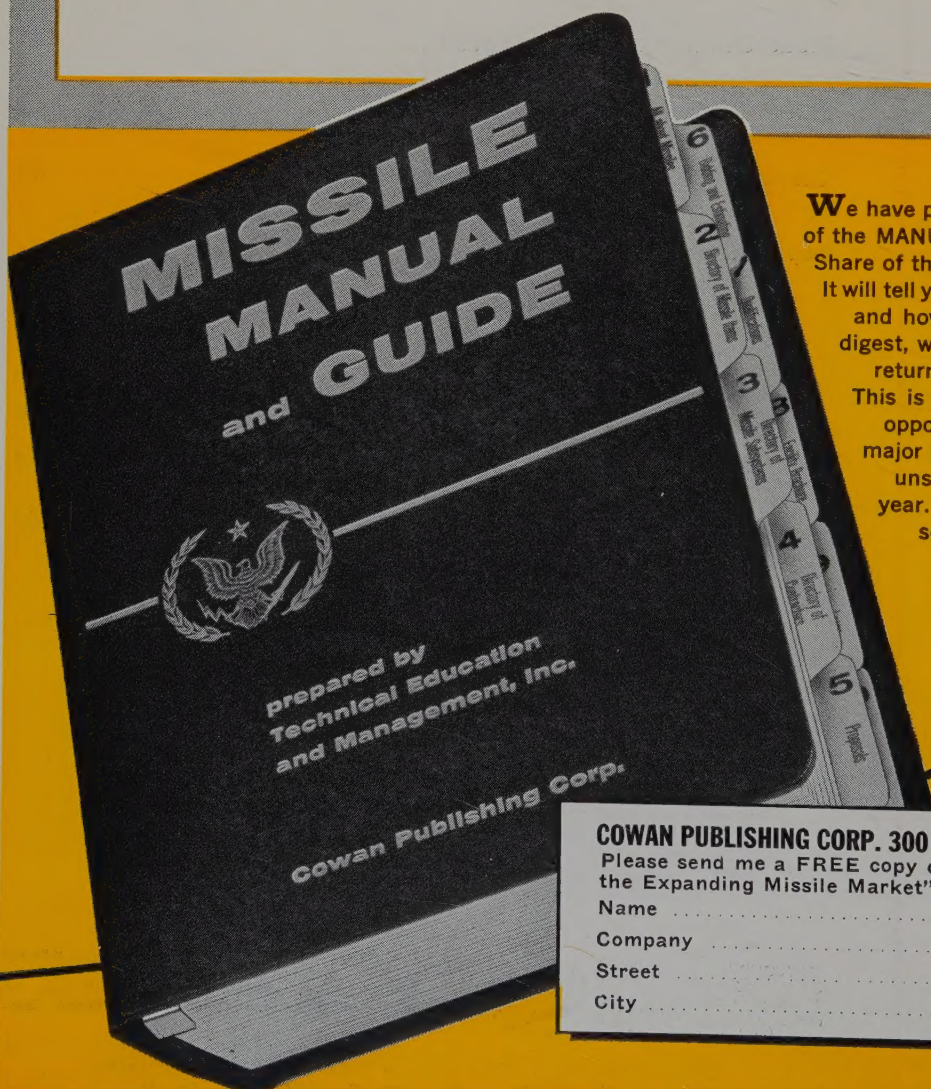
HOW TO GET YOUR SHARE OF THE 6½ BILLION DOLLAR MISSILE MARKET

During the coming year only 500 American companies will slice up the government's 6½ billion dollar missile development budget!

Yet it is estimated that more than 100,000 companies, making almost as many different products, qualify as suppliers to the missile program. Yours may be one of them.

The government, anxious to increase the number of companies supplying missile development products and services, has ordered all procurement agencies to encourage bids from every possible contractor, subcontractor or supplier. In other words, this 6½ billion dollar market is wide open!

And now there's a comprehensive, understandable "how to" GUIDE to help you get missile business—even if you've never sold to the government before! The Technical Education and Management, Inc. division of Cowan Publishing Corp. spent more than two years compiling the data for this book, THE MISSILE MANUAL AND GUIDE. It tells exactly what the government needs—paste, paper clips, paints, potentiometers, piping, and many thousands of other products—how to qualify, how to make up and submit proposals, how to bid and estimate, how to make up a facilities brochure, how to get government financing... and much, much more.



We have prepared a fast-reading digest of the MANUAL entitled "Getting Your Share of the Expanding Missile Market". It will tell you just what's in the MANUAL and how to get a copy. To get the digest, without cost or obligation, just return the coupon below.

This is your company's golden opportunity to break into the only major industrial market that is still unsaturated and growing every year. You can't afford to ignore it, so mail this coupon today!

COWAN PUBLISHING CORP. 300 W. 43rd St., New York 36
Please send me a FREE copy of "Getting Your Share of the Expanding Missile Market".

Name Position
Company
Street
City State

Circle No. 6 on Reader Service Card

SEMICONDUCTOR PRODUCTS • SEPTEMBER 1959

MERCK HAS ALL FOUR FORMS OF Silicon IN PRODUCTION QUANTITIES

***MERCK DOPED SINGLE CRYSTAL SILICON**—offers doped float zone refined single crystals of high quality at low costs. Yields of usable material are reported to be especially high when device diffusion techniques are used with these crystals. Float zone single crystals doped either "p" or "n" type with resistivities from 0.1 to 300 ohm cm. any range plus or minus 25% with high lifetimes, available in diameters of 19 to 21 mm., and random lengths of 2 to 10 inches.

NOTE: Doped single crystals float zone refined in other diameters, resistivities, or lifetimes not listed above can be furnished as specials.

MERCK HIGH RESISTIVITY "P" TYPE SINGLE CRYSTAL SILICON—offers float zone refined single crystals of a quality unobtainable by other methods. Available with minimum resistivity of 1000 ohm cm. "p" type and a minimum lifetime of 200 microseconds, diameter 18 to 20 mm., random lengths 2 to 10 inches.

MERCK POLYCRYSTALLINE BILLETS—have not previously been melted in quartz, so that no contamination from this source is possible. Merck guarantees that single crystals drawn from these billets will yield resistivities over 50 ohm cm. for "n" type material and over 100 ohm cm. for "p" type material. Merck silicon billets give clean melts with no dross or oxides.

MERCK POLYCRYSTALLINE RODS—are ready for zone melting as received... are ideal for users with float zone melting equipment. Merck polycrystalline rods are available in lengths of 8½ to 10½ inches and in diameters of 18 to 20 mm. Smaller diameters can be furnished on special order. In float zone refining one can obtain from this material single crystals with a minimum resistivity of 1000 ohm cm. "p" type with minimum lifetime of 200 microseconds or the material can be doped by user to his specifications.

***NOTE:** Extended resistivity range.

© Merck & Co., Inc.



For additional information on specific applications and processes, write Merck & Co., Inc., Electronic Chemicals Division, Department SP-99, Rahway, New Jersey.

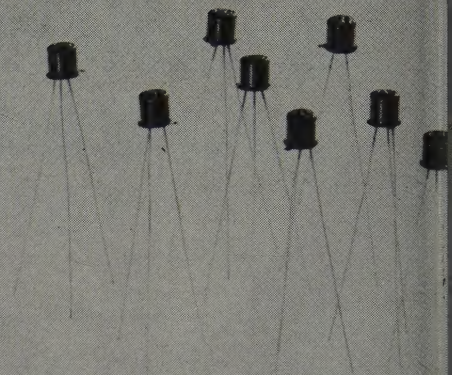
ULTRA-PURE

Silicon—a product of **MERCK**

BASE BORON CONTENT BELOW ONE ATOM OF BORON PER SIX BILLION SILICON ATOMS

Circle No. 7 on Reader Service Card

SEMICONDUCTOR PRODUCTS • SEPTEMBER 1959



NEW FAIRCHILD 2N706 provides TRANSISTOR LOGIC OF MAXIMUM

Saturating high-speed silicon logic ends the need to sacrifice one requirement in favor of another. The Fairchild 2N706 diffused silicon mesa transistor is as fast as the fastest germanium — and in addition has the inherent advantages of silicon. This combination fulfills all these logic-circuit design objectives:

SPEED

- 10 megapulse operation saturated
- 25 megapulse operation nonsaturated
- Guaranteed low storage

RELIABILITY

- Large power reserve: 150 mW dissipation at 100° C ambient (no heat sink)
- 300° C stabilization of all units
- Rugged mesa construction

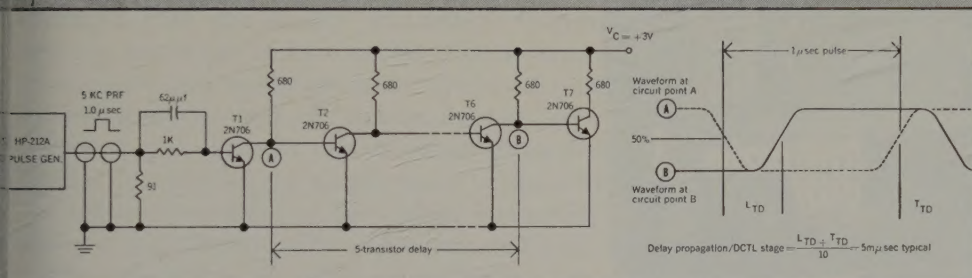
CIRCUIT SIMPLICITY

- Saturating logic with fewer components
- 3 to 5 milliampere current level
- Small JEDEC TO-18 outline

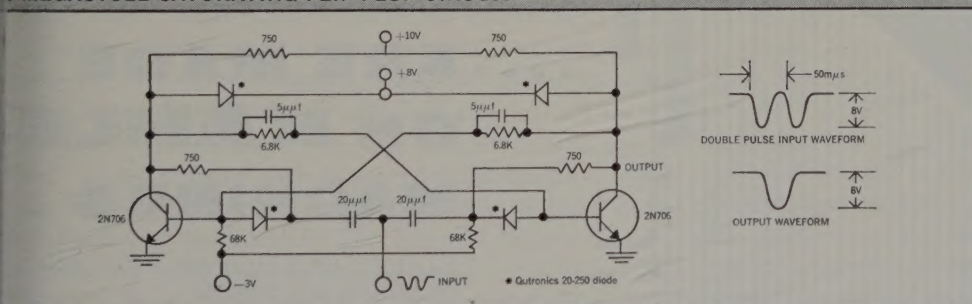
Fairchild's 2N706 provides optimum performance in the most-used logic circuit configurations and has a broad current and power range that covers many alternate approaches. It is ideally suited for high-density modular equipment because of its small size and its high performance in simple, low-power saturated circuits. The 10 megapulse speed is conservative, applying specifically to saturating logic and a 3 to 5 milliampere current level.

SPEED, RELIABILITY, SIMPLICITY

m μ SECOND PROPAGATION DELAY PER STAGE IN DIRECT COUPLED LOGIC



1 MEGACYCLE SATURATING FLIP-FLOP CIRCUIT



RATINGS AND CHARACTERISTICS (25°C) — 2N706 NPN DIFFUSED SILICON TRANSISTOR

Symbol	Characteristics	Rating	Min.	Typ.	Max.	Test Conditions
V_{CB0}	Collector to base voltage	25 v				
V_{EB0}	Emitter to base voltage	3 v				
	Total dissipation, 100° C free air ambient	150 mw				
h_{FE}	D.C. pulse current gain		15			$I_C = 10 \text{ mA}$ $V_C = 10 \text{ v}$
$V_{BE(SAT)}$	Base saturation voltage				0.9	$I_C = 10 \text{ mA}$ $I_B = 1 \text{ mA}$
$V_{CE(SAT)}$	Collector saturation voltage			0.3	0.6	$I_C = 10 \text{ mA}$ $I_B = 1 \text{ mA}$
h_{fe}	Small signal current gain at $f = 100 \text{ mc}$			4		$I_C = 20 \text{ mA}$ $V_C = 10 \text{ v}$
C_{ob}	Collector capacitance (140Kc)			3.5 pf	6 pf	$I_E = 0 \text{ mA}$ $V_C = 10 \text{ v}$

For specification sheets, write Dept.

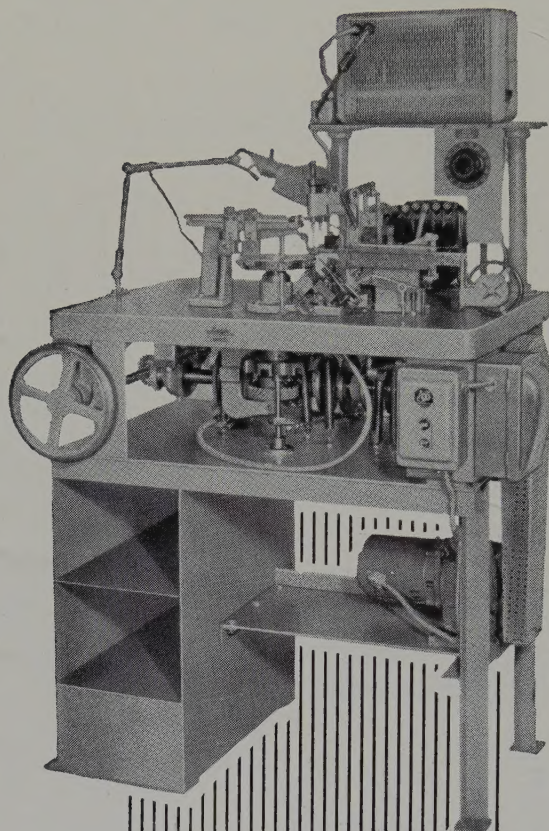


545 WHISMAN ROAD • MOUNTAIN VIEW, CALIFORNIA
YORKSHIRE 8-8161 • TWX: MOUNTAIN VIEW CAL 122

REGIONAL SALES OFFICES: Philadelphia area: 100 Old York Road, Jenkintown, Pa.
Turner 6-6623 and 6624, TWX: Jenkintown Pa 1056 • Los Angeles area:
8833 Sunset Blvd., Los Angeles 46, Calif., OLeander 5-6058 and 6059, TWX: BV 7085

Circle No. 8 on Reader Service Card

**THE BEST
GLASS
DIODES
MADE**



**....ARE MADE
ON KÄHLE
MACHINES**

**KAHLE CAT WHISKER
WELDING MACHINES...**
designed for both beaded and unbeaded lead
wires ... automatically feed, weld, cut and
form up to 3000 cat whiskers an hour.
Designed to establish new standards of
efficiency and economy in your operation,
this machine is just one example of the
full line of fine Kahle equipment for the
production of semiconductors. Moreover,
every Kahle machine is pre-tested ... under
actual operating conditions ... prior
to shipment.

For detailed information, write to:

KÄHLE
ENGINEERING COMPANY

GENERAL OFFICES:

3316 Hudson Avenue, Union City, New Jersey
LEADING DESIGNERS AND BUILDERS OF
MACHINERY FOR THE ELECTRONIC INDUSTRY

Circle No. 9 on Reader Service Card

SEMICONDUCTOR PRODUCTS • SEPTEMBER 1959

Editorial . . .

Low Temperature Avalanche Effects

As a result of the improvements in the techniques of liquefaction of helium, studies of low temperature phenomena in semiconductors have been greatly intensified. Although the novel devices proposed must compete with the devices which operate at room temperature, for convenience in practical application, the results nonetheless are of extreme interest.

A bulk avalanche effect in semiconductors at very low temperature was described recently by Sclar and Burstein (J.Phys.Chem.Solids Jan. 1957). At temperatures such that the thermal energy kT is less than the impurity activation energy in the semiconductor most carriers recombine with the impurities, and the remaining carriers acquire very large mobility. As a result, under the application of a small electric field (for example 10^5 V/cm in germanium at 4.2°K) these free carriers may be accelerated sufficiently to produce avalanche ionization by inelastic collisions with the neutral impurities. Current rise times of the order of 10^{-9} sec have been observed in germanium and applications for the construction of switching diodes and of bistable devices have been proposed. (McWhorter and Rediker; Proc.IRE July 1959). The devices are simply built because they do not require $p-n$ junction formation, but consist of a wafer of germanium with two ohmic contacts.

The possibility of pulse amplification has been pointed out by Steele, Pensak and Gold (Proc. IRE June 1959). This type of operation resembles somewhat the mechanism found in superregenerative amplifiers. The semiconductor wafer is provided with two terminal (ohmic) contacts and with a third intermediate ohmic contact. The unit is connected in series with a load resistor and driven with rectangular voltage pulses of amplitude large enough to produce bulk avalanche multiplication. The current builds up exponentially with time, but the overall current flowing through the load resistor depends on the distribution of potential along the semiconductor sample. By application of a short control pulse of polarity opposite to that of the drive pulse it is possible to enhance the value of the electric field in regions of the sample, obtaining as a result a larger integrated current. Peak power gains of the order of 20 have been obtained for pulses of durations 25 and 50 μsecs .

Japanese Semiconductor Productivity

A subject of great importance to many semiconductor manufacturers today is the increasing productivity and future potential of the Japanese semiconductor

industry. At present we in the industry, both producer and consumer, have not felt any significant effects of the Japanese industry because they have not really attempted to flood the American market with devices *per se*. They have mainly concentrated on the sale of completed equipment as evidenced by the sale of portable transistorized entertainment type receivers rather than the individual components. The cost of these end items are quite competitive with similar American products possibly because historically the Japanese have had this market in the East prior to the blossoming of our own demands.

Because of the sale of these receivers the Japanese device concentration has been in the germanium alloy junction transistor. However in the past year there has been a tendency for the Japanese transistor specifications to reflect more and more other applications, including switching. In addition there is no reason to believe that the Japanese will rest at this point. Instead, they seem to be going on to other devices and materials which may affect present industrial as well as future entertainment markets. It will be interesting to note the effect of the Japanese industry on American semiconductor production in the future, and what measures will be taken to combat a deluge of foreign devices on the market.

Growth of American Semiconductor Suppliers

The transistor industry had its birth a little over ten years ago, and with its inception new companies as well as new divisions of established electronic component suppliers were formed. During the middle era of this new industry the formation of additional companies dedicated to the manufacture of semiconductor devices was looked upon as a passing fancy. It was the opinion of the veterans of the time that as the industry "settled down" so would the number of manufacturers slowly revert to the Stalwarts of the electronic component suppliers and a very few independents.

With the past few months at least four new companies have announced their intentions of manufacturing and/or supplying semiconductor devices. This has come on the heels of the formation of many other manufacturers of semiconductor devices during the past two years. To those paying heed to the soothsayers of the industry who claim the number of companies will decrease as the industry settles down it would be well to point up the tendencies in the opposite direction and the further gains being made in the sale and application of semiconductors.

Samuel L. Marshall

A 1-WATT RESISTOR

BECOMES A

VOLTAGE STANDARD

WHEN USED WITH

A [®]REGATRON PROGRAMMABLE POWER SUPPLY

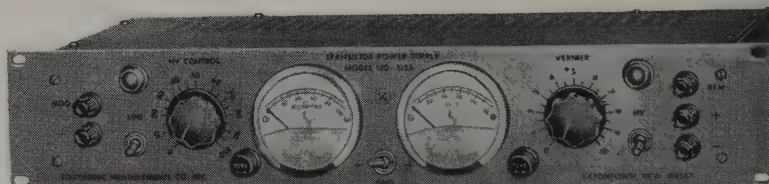


Take a 1-watt resistor. Place it across the programming terminals of a Regatron Programmable Power Supply. Instantly you've fixed the output voltage to 1/1000 of the resistance value. For example, a 22.5K resistor will fix the output at 22.5V. For a perfect repeat every time, use the same resistor. For other voltages use a different resistor. The output will always equal 1/1000 of the resistance value.

In addition, you'll find that Regatron Programmable Power Supplies have all the other advanced features you would expect in a versatile laboratory instrument; super-regulation, vernier as well as main voltage control, and more. Compare a Regatron Programmable Power Supply with any other d-c power source, batteries included. You'll find you won't settle for less.

Regatron Programmable Power Supplies are available in voltage ranges covering 0-50 V dc, 0-100 V dc, 0-300 V dc, and 0-600 V dc. Current ratings are up to 3A, depending on model. Request Bulletins 350 and 765.

(Various models without the programming feature are also available in voltage ranges up to 1000 V and currents up to 1 ampere.)

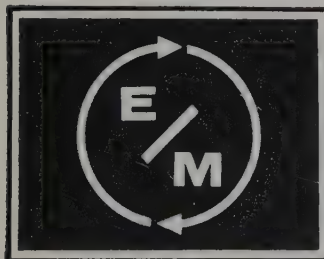


TRANSISTOR TYPES

MODEL NUMBER	OUTPUT		REGULATION				MAX- IMUM RIPPLE IN MV
	Voltage	Current	LINE 105—125 V AC 50—60 CPS		NO LOAD TO FULL LOAD		
			%	V	%	V	
212A ¹	0—100 V DC	0—100 MA	0.15	0.05	0.1	0.05	1/2
2-212A ¹	EQUIVALENT TO TWO MODEL 212A's. OUTPUTS MAY BE USED IN SERIES, PARALLEL, OR INDEPENDENTLY.						
224A ¹	0—100 V DC	0—200 MA	0.15	0.05	0.1	0.05	1
220A	0—50 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
221A	0—100 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
213A	0—50 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
214A	0—100 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
215A	0—50 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1
218A	0—100 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1

1. Modulation input provided for measurement of transistor parameters by small signal method.

® REGISTERED U.S. PATENT OFFICE. PATENTS ISSUED AND PENDING.



ELECTRONIC
MEASUREMENTS
 COMPANY, INCORPORATED
 EATONTOWN • NEW JERSEY

Circle No. 10 on Reader Service Card

crystal growing with Trancoa silicon . . .

**single,
single
all
the way**

POLYCRYSTALLINE SILICON SPECIFICATIONS

Grade	Resistivity P-Type	Max. Resistivity Ratio for 10% & 60% Points	Max. Boron Content (ppb)
IA	500	3:1	0.5
I	100	3:1	1.0
II	50	3:1	2.0
III	25	3:1	7.0
IV	2.5	3:1	—

Consistently clean Trancoa Silicon eliminates the twins, polys, and dropped charges that can result from dirty material. This will give you a larger yield of single crystal per pound of silicon . . . saving material, saving machine time, saving labor.

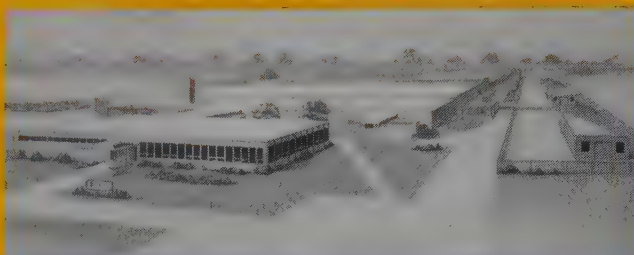
We prove the cleanliness of our Silicon at Trancoa by growing test crystals with only 3/16th of an inch

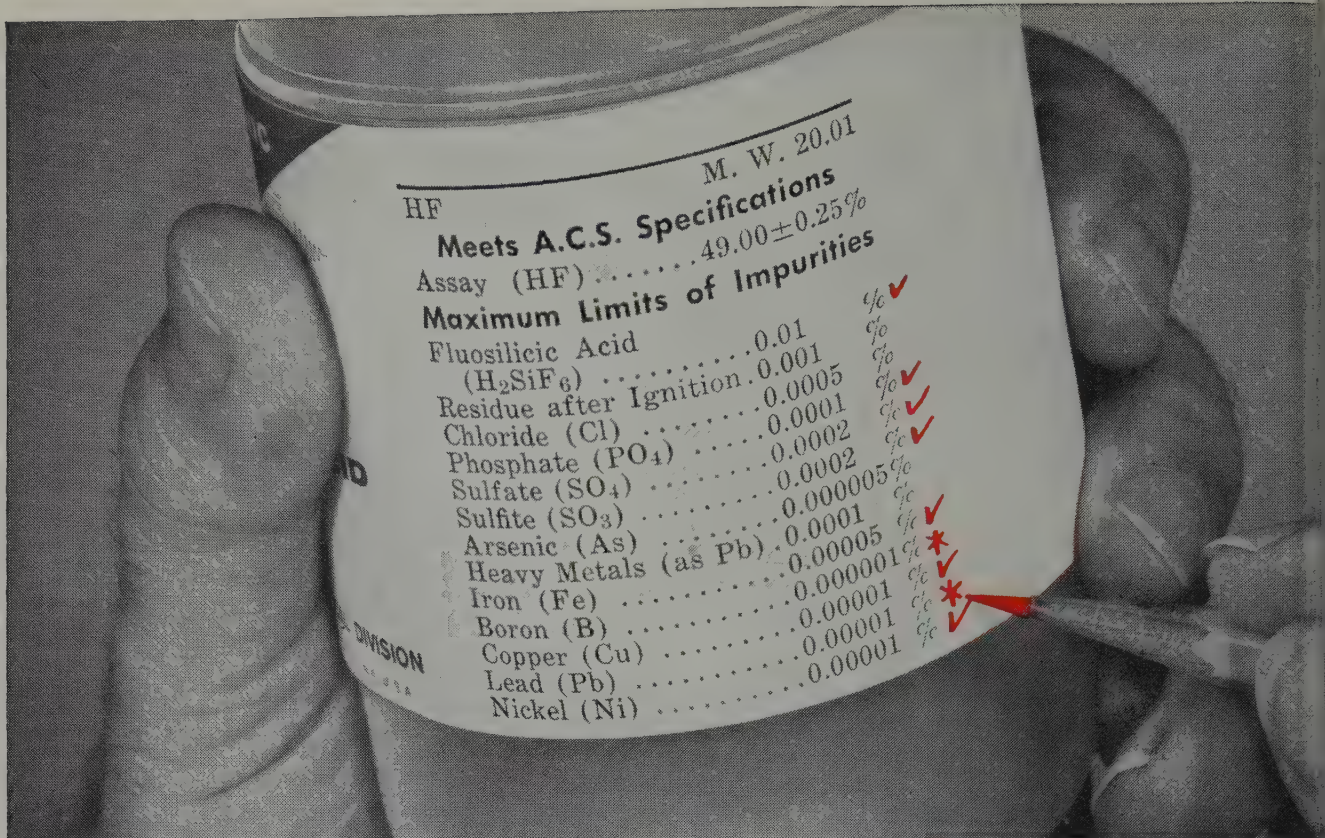
between crucible and crystal . . . and they are single, single all the way! You can be confident of achieving uniform results within a lot and from one lot to another by growing crystals with Trancoa Silicon.

See table for the five grades available. Complete information is contained in "Trancoa Methods for Evaluating Silicon". Write today for a copy.

Trancoa
chemical corporation

312-326 Ash Street, Reading, Massachusetts
Tel. REading 2-3900





✓ Check these stringent specifications.
✗ Now added for the first time

BAKER & ADAMSON® ANNOUNCES HIGHEST PURITY YET FOR "ELECTRONIC GRADE" HF

For years, Baker & Adamson's "Electronic Grade" Hydrofluoric Acid has been the purest available. Now, to serve electronic requirements even better, this high purity has been still further improved.

Utilizing the most advanced production techniques and quality control methods, B&A is now making its "Electronic Grade" HF Acid to meet stringent new specifications in which impurities are held to the lowest levels ever attained. In addition, maximum limits for boron and lead have been established and are included for

the first time . . . enabling still further control of impurities. Result: B&A "Electronic Grade" Hydrofluoric Acid offers greater reliability in critical etching operations . . . helps reduce rejects and improves quality control in the production of semiconductors.

These new ultra pure specifications for "Electronic Grade" HF point up Baker & Adamson's continued leadership in supplying high purity production chemicals for the electronic industry. B&A "Electronic Grade" Hydrofluoric Acid is

available in 1 lb. plastic bottle, 10 lb. returnable plastic jug, 10 lb. non-returnable polyethylene bottle, and 6½ lb. polyethylene carboy. Remember . . . for the finest in electronic chemicals—specify B&A!

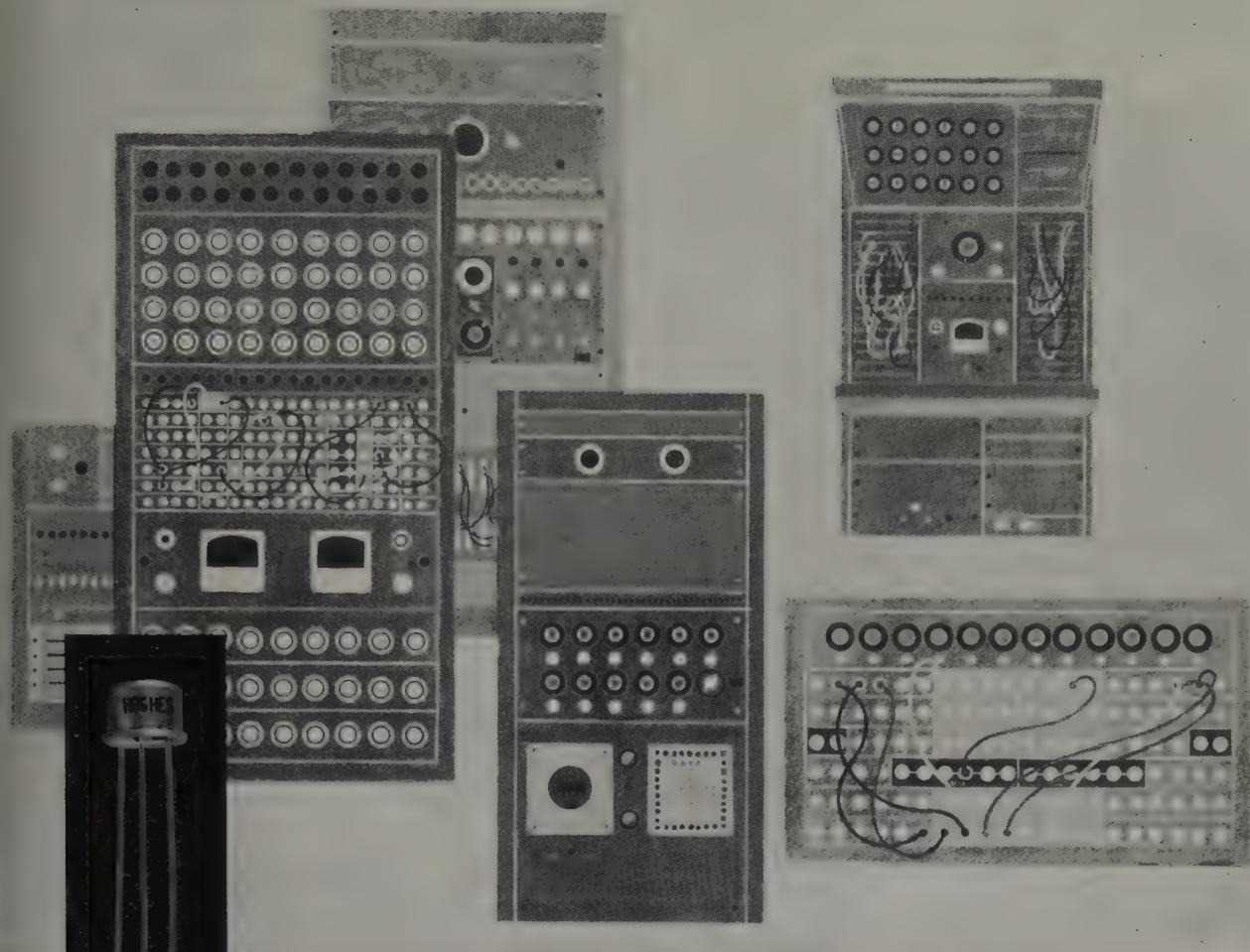
Quality specifications have also been improved for B&A Reagent Hydrofluoric Acid, 48% A.C.S. The new reagent grade promises greater reliability in research . . . fewer variables in laboratory control work . . . better analytical control . . . more reproducible results.

BAKER & ADAMSON®
"Electronic Grade" Chemicals



GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

Circle No. 12 on Reader Service Card



HIGH-SPEED COMPUTER SWITCHING TRANSISTORS

SILICON DDMT—Double Diffused Mesa Transistor . . . now available from Hughes to solve your high-speed

switching problems. This new silicon PNP transistor, which operates at low and medium current levels, gives you a cut-off frequency greater than 50 megacycles. In addition, Beta—as a function of collector current—is flat over 80 per cent of the operating range.

Two other advantages: 1. This Hughes transistor offers you all the desirable characteristics inherent in the solid state diffusion technique. 2. The tiny flexible leads of its gold plated package may be soldered directly into circuits or used with standard plug-in sockets.

This new device, while designed primarily for computers, is also an excellent amplifier and oscillator, lending itself to an unusually broad range of applications.

As in all Hughes semiconductor devices, reliability has been specifically designed into this mesa transistor. They are manufactured in the new multi-million dollar Hughes Semiconductor facility . . . using the finest equipment and newest techniques.

Your inquiry regarding these transistors will be given prompt attention. Just write or call the Hughes sales office nearest you.

They are located in:

Boston, 4 Federal Street; **Woburn, Mass.**; **Wells** 3-4824

Minneapolis, 6121 Excelsior; **Minneapolis 16, Minn.**; **WEst** 9-0461

Newark, 80 Mulberry Street; **Newark 2, N. J.**; **MArket** 3-3520

San Francisco, 535 Middlefield Road; **Palo Alto, Calif.**; **DA** 6-7780

Syracuse, 224 Harrison Street; **Syracuse 2, N. Y.**; **GRanite** 1-0163

Chicago, 1515 N. Harlem Ave.; **Oak Park, Ill.**; **NAtional** 2-0283

Cincinnati, 816 Swifton Center; **Cincinnati, Ohio**; **ELmhurst** 1-5665

Philadelphia, 1 Bala Avenue; **Bala-Cynwyd, Penn.**; **MOhawk** 4-8365

Los Angeles, 690 N. Sepulveda; **El Segundo, Calif.**; **OR** 8-6125

Or write, Hughes Products, Marketing Department,
SEMICONDUCTOR DIVISION, NEWPORT BEACH, CALIFORNIA.

For export, write: Hughes International, Culver City, Calif.

SPECIFICATIONS: Absolute Maximum Ratings (25°C)

	2N1254	2N1255	2N1256	2N1257	2N1258	2N1219
BV_{CEO}	15V	15V	30V	30V	50V	50V
BV_{CBO}	15V	15V	30V	30V	50V	50V
BV_{EBO}	5V	5V	5V	5V	50V	3V
Power Dissipation	250 mw					
Ambient Temperature	-65°C + 175°C					

SEMICONDUCTOR DIVISION

Creating a new world with **ELECTRONICS**

HUGHES PRODUCTS

© 1959, HUGHES AIRCRAFT COMPANY

SEMICONDUCTOR DEVICES • STORAGE TUBES AND DEVICES • MICROWAVE TUBES • VACUUM TUBES AND COMPONENTS • CRYSTAL FILTERS • MEMO-SCOPE® OSCILLOSCOPES • INDUSTRIAL CONTROL SYSTEMS

Circle No. 13 on Reader Service Card

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST No. 13

Preliminary Investigation of Transistorized Saturable-Core D-C to A-C Converters at Frequencies above 2 kc; Lansdale Tube Co., Lansdale, Pa.

This investigation was initiated in response to a request for a d-c to a-c converter capable of delivering 20 watts from a 12 volt source at an output frequency between 3 kc and 12 kc.

Circuits Tested

Two balanced push-pull circuits with grounded collectors were tested—a common emitter circuit, (Fig. 13.1), and a common collector circuit. A common base circuit was not tested because such a network does not permit the collector to be grounded. Grounding the collector is desirable in order to provide a non-insulated thermal conductance from the collector junction to the chassis, thereby permitting operation at higher power outputs and/or higher ambient temperatures. If desired, the load can be driven from secondary windings. A silicon diode bridge rectifier was employed to facilitate measurements of the output power.

Comments

(1) At the higher frequencies the ferrite core is preferable to the tape-wound core, since the core losses in the latter become excessive, being on the order of 6-7 watts per ounce of core with 2-mil thick orthonol tape when driven to saturation at 10 kc. At 5 kc, the losses are rated at approximately 2-3 watts per ounce. The core material in the tape-wound unit that was used weighed approximately 1.5 ounces. The ferrite core not only was much lighter, but its power loss per unit weight was also much less. At the lower frequencies, however, the wave forms observed were generally smoother for the tape-wound

core than for the ferrite core. The reasons for this were not investigated, but it is quite likely that with the manual method of winding, the leakage reactance simply happened to be significantly greater in the one case than in the other.

(2) The power transistors, Philco 2N352 units, were selected because of their low cost. At the higher frequencies, the transformer voltage wave form was quite distorted from the characteristic saturable-core, square wave shape. It is believed that this distortion was due primarily to the limitations in the time response of the transistors, for when replaced by high-frequency transistors the distortion disappeared.

(3) To insure dependable starting without an initial negative base bias, it was decided from previous experience that the N_f/N_p ratio at different frequencies should be approximately 0.3. Other values of the turns ratio were tried when testing the general circuit behavior at different frequencies; however, measurements have not been made with the ratio as a controlled independent variable at constant N_p or constant frequency.

(4) A 0.3 turns ratio implies a 4-volt induced emf in the feedback during the

"on" alternation of each cycle, so that additional resistance, R_f , was inserted in each feedback circuit to reduce the base current and hence the feedback power loss. The efficiencies at frequencies above 12 kc were measured with R_f equal to 12 ohms, and below 12 kc with R_f equal to 6 ohms. However, direct comparisons have not been made with R_f as an independent variable while the other circuit parameters were held constant.

(5) For an ideal saturable-core hysteresis loop and instantaneous switching time, the converter frequency is given by the formula:

$$f = \frac{V_{in}}{4 N_p \phi}, \text{ or } f N_p = \text{constant}$$

where ϕ is the total flux at saturation and V_{in} is the d-c input supply voltage applied across the transistor and N_p in series. (The actual emitter-to-collector voltage across each transistor will vary from approximately 0.1 or 0.2 volts during the "on" alternation to $2 V_{in}$ during the "off" alternation of each cycle. Under full load conditions the $f \cdot N_p$ product did not remain a constant. This nonlinearity seemed primarily due to the fact that the switching time of the transistors occupied a significant frequency-variable portion of each cycle, rather than because of core irregularities. Had the latter factor been the greater, the deviation of $f \cdot N_p$ would have been approximately as large under no-load as under full-load operation, but this was not observed. Further, the ragged wave forms, indicative of the prolonged switching action, were converted into relatively smooth square waves when the 2N352 units were replaced by hf transistors.

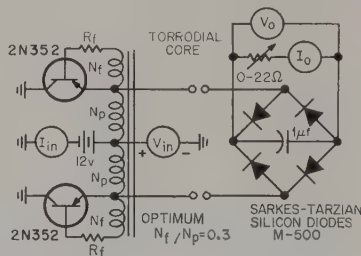


Fig. 13.1—DC to AC converter.

Circle 198 on Reader Service Card

APPLICATIONS ENGINEERING DIGEST No. 14

Circuit Applications for Diffused Silicon Regulators, Texas Instruments Inc., Dallas, Texas.

Power regulator or Zener diodes have characteristics that are particularly well suited for shunt regulator applications. The current-voltage characteristic has a sharp break at approximately 0.1 ma. Beyond this point, the voltage across the diode remains almost constant for currents up to the maximum value obtained at the allowable power dissipation. The flat voltage characteristic is

quite similar to a gas-tube regulator characteristic. The power regulator diode provides a wider choice of voltages and larger current ranges than do gas-tube regulators. In addition to these advantages, it does not require a firing voltage higher than the regulating voltage, as does a gas-tube regulator.

Shunt Regulated Power Supply

The power zener diodes provide a simpler means of obtaining a regulated d-c transistor bias supply. The advan-

tage of this supply is the absence of transformers and chokes, while furnishing a regulated low voltage d-c with low ripple. (see Fig. 14.1)

The voltage provided at the 100 ma capacitor by the bridge rectifier is 11.5 volts d-c with 11.5 volts peak to peak ripple. The resistor R-2 and the filter regulator, 1N1829 provide additional filtering, reducing the ripple by a factor of 180, while reducing the voltage to

[continued on page 16]

10 Mc. Voltage Gain
 Delay action is that of RCA-2N1301
 RCA-2N1301 Mesa Transistor

RCA-2N1300 and 2N1301

LOW-COST MESA COMPUTER TRANSISTORS

Now in quantity production... and available!

RCA-2N1300 and 2N1301 Germanium P-N-P Mesa Transistors offer these 10 major benefits to designers of switching circuits. And they're ready for you now!

- rugged Mesa structure—permits extremely small base width to insure top performance at high frequencies
- fast switching times with low values of base input current—made possible by high frequency response and low total stored charge
- high current gain—permits high fan-out ratios (number of paralleled similar circuits per driver-stage output)
- high breakdown voltage and punch-through voltage ratings—the result of the diffusion process
- high power dissipation—150 milliwatts at 25°C— aids in the design of reliable circuits
- high current ratings—improve overall system speed
- rugged overall design—units have unusual capabilities to withstand severe drop tests and electrical overloads
- electrical uniformity—a result of the diffused-junction process used by RCA in the manufacture of Mesa Transistors
- especially well suited for use at pulse repetition rates up to 20 Mc
- exceptionally well suited to applications in saturation-type switching circuits

Information on RCA-2N1300 and 2N1301 Low-Cost Mesa Transistors is available from your RCA Field Representative. For technical data, write RCA Commercial Engineering, Section 1-100-NN, Somerville, N.J.

RCA TYPE	Maximum Ratings* Absolute-Maximum Values						Characteristics: Common-Emitter Circuit, Base Input Ambient Temperature of 25°C		
	Collector- to-Base Volts	Emitter- to-Base Volts	Collector Milli- amperes	Transistor Dissipation—mw			Minimum DC Current Gain		Gain Bandwidth Product* Mc
				at 25°C	at 55°C	at 71°C	at collector ma = -10	at collector ma = -40	
2N1300	-13	-1	-100	150	75	35	30	—	40
2N1301	-13	-4	-100	150	75	35	30	40	60

*Maximum collector-to-emitter
voltage rating = -12 volts

For collector ma = -10 and
collector-to-emitter volts = -3.

RCA Field Offices

EAST: 744 Broad St., Newark 2, N. J.
Humboldt 5-3900

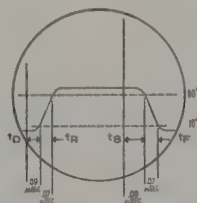
NORTHEAST: 64 "A" Street
Needham Heights 94, Mass.
Hillcrest 4-7200

EAST CENTRAL: 714 New Center Bldg.
Detroit 2, Mich.
Trinity 5-5600

CENTRAL: Suite 1154
Merchandise Mart Plaza
Chicago 54, Ill.
Whitehall 4-2900

WEST: 6355 E. Washington Blvd.
Los Angeles 22, Calif.
RAYmond 3-8361

GOV'T: 224 N. Wilkinson Street
Dayton, Ohio
BALdwin 6-2366
1625 "K" Street, N.W.
Washington, D. C.
District 7-1260



Oscilloscope wave form shows typical delay, rise, storage, and fall times achieved with 10-ma inverter circuit utilizing the RCA-2N1301 MESA TRANSISTOR.



RADIO CORPORATION OF AMERICA

SEMICONDUCTOR AND MATERIALS DIVISION • SOMERVILLE, N. J.

ALSO AVAILABLE THROUGH YOUR LOCAL
RCA SEMICONDUCTOR DISTRIBUTOR.

This package can end your worries about silicon processing . . .



Inside this box you'll find doped silicon single crystal slices from Allegheny.

Who needs them? You do . . .

If you wish to increase production without tying up capital in facilities for slicing, lapping, etching and such.

If you'd like to avoid being dependent on just one source of supply.

You solve either (or both) of these problems with Allegheny's new service because you get single crystal slices that are ready for use.

These slices from vertically pulled or float zoned crystals are doped to range with 99.999% group III and/or V elements. Standard thicknesses from .005" to .020" and diameters from 1/4 to 1 1/2 inches.

As for lapping, this we do to your specification. If you wish, we prepare one or both sides for diffusion. Otherwise slices are etched, cleaned and dried before being delivered to you.

Details? We'll provide answers to your questions, promptly.

NOTE: You'll find that Allegheny devotes its efforts exclusively to producing ultra-pure silicon in every form. You might also be interested in more facts about bulk, billets, rods, doping alloys, seeds or special forms.

If so, write, wire or phone:

Allegheny Electronic Chemicals Co.
207 Hooker-Fulton Bldg., Bradford, Pa.
252 North Lemon St., Anaheim, Calif.

ALLEGHENY

ELECTRONIC CHEMICALS CO.

Producers of semiconducting materials for the electronics industry.

volts. The value of the series resistor, $R-2$, was calculated to allow a current of approximately 50 ma to pass through the first diode, at a nominal input of 120 volts rms.

The second regulator provides further ripple reduction, (a factor of 16 at full load) and regulates the output voltage for load variations from 0 to 150 ma. The output voltage drops about 2% when the load is changed from 0 to 150 ma, giving an output resistance of approximately 3.3 ohms.

The circuit will take input fluctuations from 100 to 140 volts with little effect on the output. If lower voltages are expected, the circuit may be designed so that the 1N1829 will carry a larger current at 115 volts. The upper limit is imposed by the rating of the 1N1829.

Transistor Surge Protectors

The power handling capabilities of the 1N1821 series make them particularly well suited for surge protection of expensive power transistors. A complete voltage range of diodes available makes it possible to protect transistors of almost every collector voltage rating. The regulator diode breakdown voltage should be chosen just below the transistor zener voltage so that it will shunt surge peaks, but not interfere with normal operation.

A typical surge protection application of the power regulator diodes is illustrated in Fig. 14.2. The two 2N457 germanium power transistors used in the converter have a maximum voltage rating of 60 volts. These transistors are protected from punch-through by the 56 volt 1N1831 regulators which shunt surge peaks, but do not interfere with normal operation of the circuit. The double anode feature of these diodes make them applicable to the protection of either *p-n-p* or *n-p-n* transistors, without having to be insulated from the heat sink.

Arc Suppression

The ability of power zener diodes to handle high surges may be applied in arc suppression. The high non-recurrent peak rating allows the diodes to dissipate surge power which would otherwise cause contact arcing and deterioration, insulation breakdown, and wide-band electrical interference.

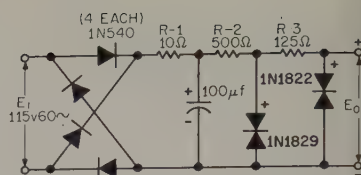


Fig. 14.1—Shunt regulation.

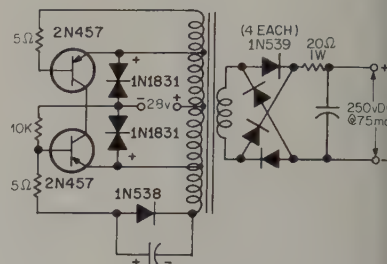


Fig. 14.2—Surge protection circuit.

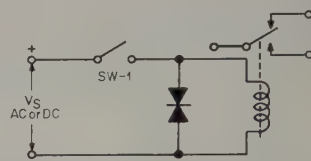


Fig. 14.3—Arc suppression by surge limiting.

A surge suppression application of the double anode clipper diode is shown in Fig. 14.3. The double anode feature permits the diode to be used in either *a-c* or *d-c* inductive circuits. The diode used in this application should have a "Zener" voltage slightly greater than the peak supply voltage, V_s . This allows normal operation of the relay circuit when the switch (SW-1) is closed. The instant the switch is opened the inductance causes a high voltage surge. As the surge voltage reaches the diode breakdown voltage, the diode resistance drops to a very low value, and thus suppresses contact arcing by limiting the peak surge voltage.

Circle 199 on Reader Service Card

APPLICATIONS ENGINEERING DIGEST No. 15

Application of High Frequency "y" Parameters, Fairchild Semiconductor Corp., Palo Alto, Calif. (G. Reddi)

As the use of transistors in *r-f* amplification is ever increasing, it is essential for a designer to understand the small-signal properties of the transistors at those frequencies. For this purpose, the functional model of a transistor can be considered as a linear active two-port network, which can be specified at a particular frequency by a set of four independent parameters. These parameters completely characterize the de-

vice for power gain considerations. In transistor work the most commonly used parameters are the "y" (short circuit admittances) and the "h" (hybrid) parameters. Each of these sets involves two immittances measured at the input and output terminal pairs (the opposite terminal pair being either open or short-circuited), and two transfer parameters.

In this memorandum the *y* parameter representation of linear two-port devices and the measurement of transistor *y* parameters at high frequencies are discussed. Different ways of designing

[continued on page 17]

single stage transistor amplifiers using small-signal two-port parameters are indicated. The usefulness of y parameters in the investigation of the potential instability and the calculation of maximum available power gain of a transistor is demonstrated. A numerical example is worked out using y parameters in amplifier circuit design.

Measurement of Transistor "y" Parameters at High Frequencies

The short-circuit measurements indicated in the various definitions of the y parameters can be readily made, using simple bridge techniques. A three-terminal device like a transistor triode can be connected in three different ways—namely common base, common emitter and common collector. Associated with these three orientations there are six driving points and three transfer admittances that can be measured, but measurement of certain combinations of four admittances out of the above nine will be sufficient to characterize the transistor in any orientation. The choice of the four parameters to be measured depends on the ease of measurement, accuracy desired, usefulness of direct reading type of measuring equipment available, etc. The Wayne Kerr B801 VHF Admittance Bridge (range 1mc-100mc), which is one of the well-suited instruments for y parameter measurements, is being used for this work. The parameters being measured are y_{11e} , y_{22e} , y_{12e} and y_{21b} . (The subscripts "b" and "e" refer to grounded base and grounded emitter configurations respectively).

Simplified diagrams of the Wayne Kerr B801 bridge and the circuits to measure the above-mentioned four y parameters are shown in Figs. 15.1 and 15.2. It should be noted that the neutral terminal N is left open when driving

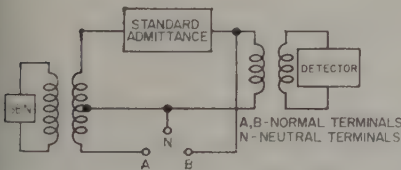


Fig. 15.1—Simplified diagram of the Wayne-Kerr B801 Bridge.

point admittances are measured. The values of capacitances in the above-shown circuits are chosen such that they offer a good short circuit at the frequency of measurement.

Design of Single Stage Narrow Band Transistor R.F. Amplifier Using y Parameters

The transducer gain, defined as the ratio of actual load power to the power available from the source when the transistor is neutralized, can be calculated by the relation:

$$G_{T \text{ neutralized}} = \frac{4 [y_{21} - y_{12}]^2 g_s g_L}{[(y_s + y_{11} + y_{12})(y_L + y_{22} + y_{12})]^2}$$

If the source and load admittances provide conjugate matches after neutraliza-

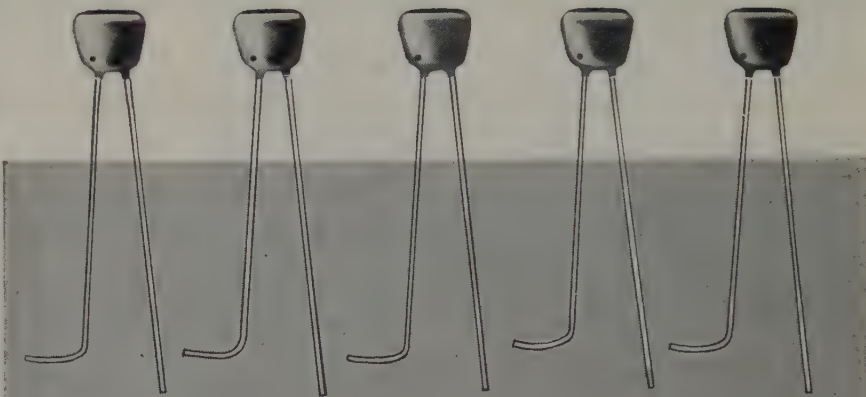
[continued on page 62]

FROM GENERAL INSTRUMENT CORPORATION

NOW... HIGH RELIABILITY FOR PENNIES!



RADIO RECEPTOR SELENIUM DIODES



PRICED FROM **15¢** TO **35¢** EACH

small size... μ a leakage

TYPICAL
UNITS

- 1XH — Half wave — 50 PIV, 12.5 Ma
- 2XH — Half wave — 100 PIV, 12.5 Ma
- 4XH — Half wave — 200 PIV, 12.5 Ma
- 5XH — Half wave — 250 PIV, 12.5 Ma
- 8XH — Half wave — 400 PIV, 12.5 Ma

Also available as doubler, center tap, 4-way bridge and special circuits.

For complete information, write today to Section SP-2



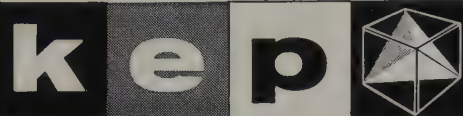
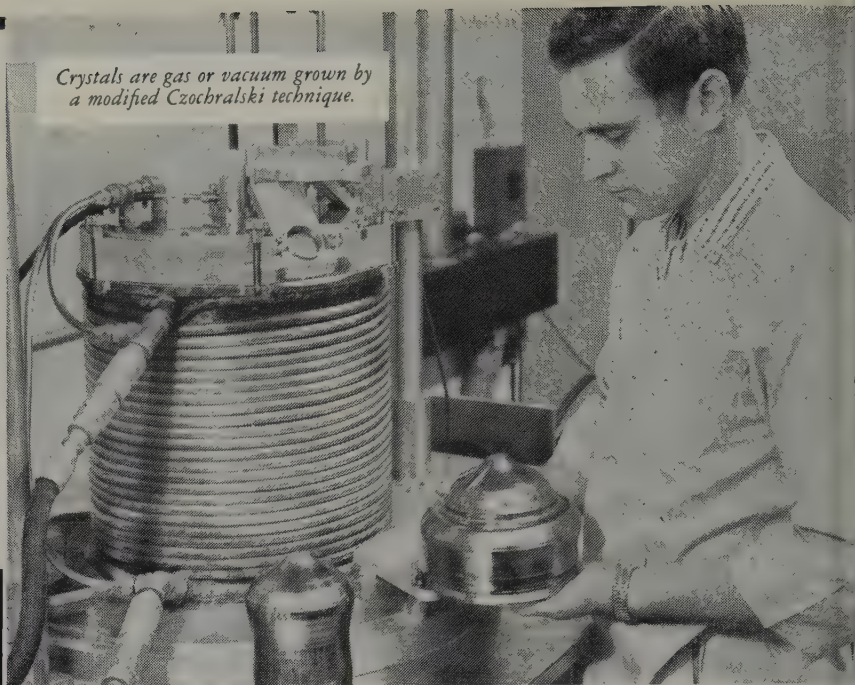
RADIO RECEPTOR COMPANY, INC.
Subsidiary of General Instrument Corporation
240 Wythe Avenue, Brooklyn 11, N. Y.

General Instrument Corporation includes F. W. Sickles Division, Automatic Manufacturing Division, Radio Receptor Co., Inc., Micamold Electronics Manufacturing Corporation and Harris Transducer Corporation (Subsidiaries)

Circle No. 16 on Reader Service Card

Let KNAPIC
grow your
SILICON
CRYSTALS
for you!

Crystals are gas or vacuum grown by
a modified Czochralski technique.



SILICON AND GERMANIUM MONOCRYSTALS

For Semiconductor,
Solar Cell and
Infrared Devices

Major manufacturers of semiconductor devices have found that Knapic Electro-Physics, Inc. can provide production quantities of highest quality silicon and germanium monocrystals far quicker, more economically, and to much tighter specifications than they can produce themselves. Knapic Electro-Physics has specialized in the custom growing of silicon and germanium monocrystals. We have extensive experience in the growing of new materials to specification. Why not let us grow your crystals too?

Knapic monocrystalline silicon and germanium is available in evaluation and production quantities in all five of the following general grade categories—Zener, solar cell, transistor, diode and rectifier, and high voltage rectifier.

SPECIFICATIONS—Check These Advantages

- ☐ **Extremely** low dislocation densities.
- ☐ **Tight** horizontal and vertical resistivity tolerances. Resistivities available in controlled ranges .005 to 1000 ohm cm., N and P type.
- ☐ **Diameters** from .10" to 2". Wt. to 250 grams per crystal. Individual crystal lengths to 10".
- ☐ **Low Oxygen** content 1×10^{17} per cc., 1×10^{16} for special Knapic small diameter material.
- ☐ **Doping** subject to customer specification, usually boron for P type, phosphorus for N type.
- ☐ **Lifetimes:** 1 to 15 ohm cm.—over 50 microseconds; 15 to 100 ohm cm.—over 100 microseconds; 100 to 1000 ohm cm.—over 300 microseconds. Special Knapic small diameter material over 1000 microseconds.

Specification Sheets Available



Dislocation density, Knapic silicon monocrystals. Crystal diameter 1/10" to 3/8"—None; 3/8" to 3/4"—less than 10 per sq. cm.; 3/4" to 1-1/4"—less than 100 per sq. cm.; 1-1/2" to 2" less than 1000 per sq. cm.



Infrared Domes and Lenses

**LARGE DIAMETER
SILICON LENSES
AND CUT DOMES
FOR INFRARED USE.**

Individual silicon ingots for lens use and hollow cut domes to 8" diameter are now available in production and evaluation quantities. Diameters up to 19" will be available in the near future. Transmission characteristics—minimum 52%, coated 97% in ranges between 1 to 15 microns.

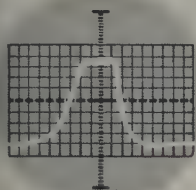
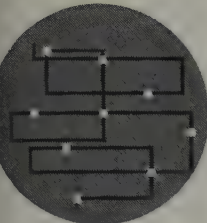
Quotations will be prepared on request for production orders, for semiconductor materials not falling within the listed categories, or for those requiring additional experimental work.

Knapic Electro-Physics, Inc.

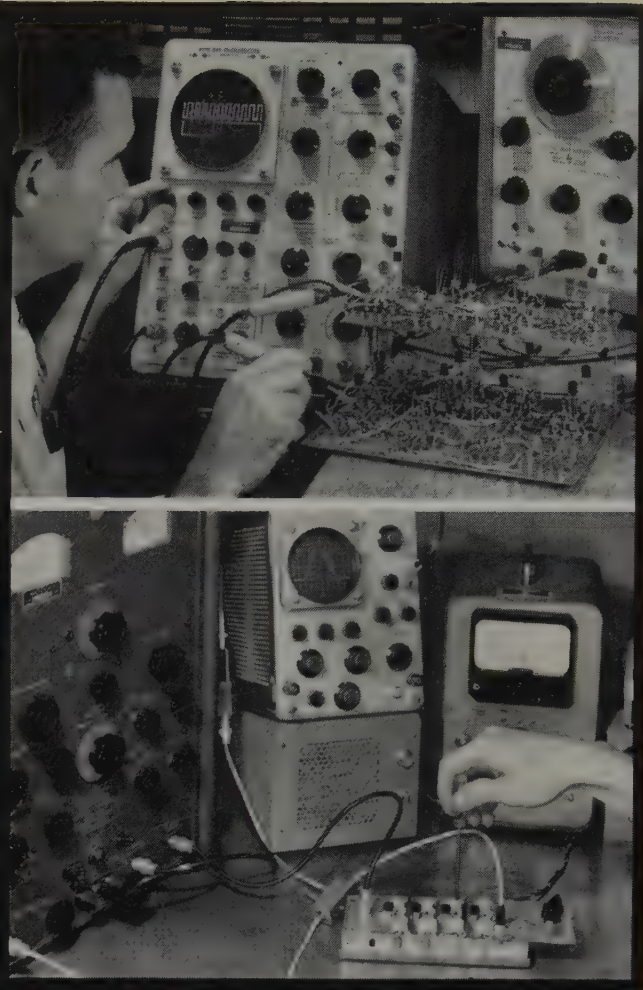
936-938 Industrial Avenue, Palo Alto, California Phone: DAvenport 1-5544

Circle No. 17 on Reader Service Card

CAREER
OPPORTUNITIES
AT TI



CIRCUIT DEVELOPMENT ENGINEER



your future: a challenging opportunity with an industry leader

At Texas Instruments, your future is filled with specific, stimulating growth assignments in evaluating and characterizing transistors and special semiconductor devices. You'll participate in such transistorization projects as:

- AM, FM, and TV receivers
- audio and video, i-f and r-f amplifiers
- hi-fi and electronic organs
- nonlinear and switching circuits
- computer system logic
- servo and power amplifiers

With TI...receive liberal company-paid benefits, including profit sharing (last year 15% of base salary) ... enjoy premium living in a moderate climate with excellent neighborhoods, schools and shopping facilities...work in a plant selected as one of the 10 outstanding U. S. industrial buildings of 1958.

Interviews will be held in your area soon. If you have an Electrical Engineering degree and/or knowledge of transistor circuitry, please send a resume to

C. A. Besio, Dept. 200

TEXAS  INSTRUMENTS
INCORPORATED
SEMICONDUCTOR - COMPONENTS DIVISION
POST OFFICE BOX 312 • DALLAS, TEXAS

For
immediate
Eastern
appointment,
contact
H. C. Laur
Dept. 200-E
1141 E. Jersey St.
Elizabeth, N. J.

UNITED CARBON PRODUCTS COMPANY

UNITED

SEMICONDUCTOR
GRAPHITE
PRODUCTS

UNITED CARBON PRODUCTS COMPANY
Bay City, Michigan

UNITED CARBON PRODUCTS COMPANY
Bay City, Michigan

made by our average client not just plant for plant but for typical

...the ...
...the ...
...the ...
...the ...
...the ...

Upon the liberations of our Technological
as this... which... is built the firm
... each... where necessary
This is... for our production
... With the present time and prog-
... nature, as these... our...
... and any... need a
... is... of im-
... every... and...
... the... our Technological
... is maintained.
... (or... but, re-
... an... a good
... a... that
... and... for many
... and...

פיר דאס צווייטע בוך, וואס איז דאס צווייטע בוך
 וואס איז דאס צווייטע בוך, וואס איז דאס צווייטע בוך
 וואס איז דאס צווייטע בוך, וואס איז דאס צווייטע בוך

1953 THE UNIVERSITY OF CHICAGO, CHICAGO, ILL. 60637
 1954 THE UNIVERSITY OF CHICAGO, CHICAGO, ILL. 60637
 1955 THE UNIVERSITY OF CHICAGO, CHICAGO, ILL. 60637

The Insurance of Multiple Quality Content

✓ 1. 1995 2. 1996 3. 1997 4. 1998 5. 1999 6. 2000 7. 2001 8. 2002 9. 2003 10. 2004 11. 2005 12. 2006 13. 2007 14. 2008 15. 2009 16. 2010 17. 2011 18. 2012 19. 2013 20. 2014 21. 2015 22. 2016 23. 2017 24. 2018 25. 2019 26. 2020 27. 2021 28. 2022 29. 2023 30. 2024 31. 2025 32. 2026 33. 2027 34. 2028 35. 2029 36. 2030 37. 2031 38. 2032 39. 2033 40. 2034 41. 2035 42. 2036 43. 2037 44. 2038 45. 2039 46. 2040 47. 2041 48. 2042 49. 2043 50. 2044 51. 2045 52. 2046 53. 2047 54. 2048 55. 2049 56. 2050 57. 2051 58. 2052 59. 2053 60. 2054 61. 2055 62. 2056 63. 2057 64. 2058 65. 2059 66. 2060 67. 2061 68. 2062 69. 2063 70. 2064 71. 2065 72. 2066 73. 2067 74. 2068 75. 2069 76. 2070 77. 2071 78. 2072 79. 2073 80. 2074 81. 2075 82. 2076 83. 2077 84. 2078 85. 2079 86. 2080 87. 2081 88. 2082 89. 2083 90. 2084 91. 2085 92. 2086 93. 2087 94. 2088 95. 2089 96. 2090 97. 2091 98. 2092 99. 2093 100. 2094 101. 2095 102. 2096 103. 2097 104. 2098 105. 2099 106. 2100 107. 2101 108. 2102 109. 2103 110. 2104 111. 2105 112. 2106 113. 2107 114. 2108 115. 2109 116. 2110 117. 2111 118. 2112 119. 2113 120. 2114 121. 2115 122. 2116 123. 2117 124. 2118 125. 2119 126. 2120 127. 2121 128. 2122 129. 2123 130. 2124 131. 2125 132. 2126 133. 2127 134. 2128 135. 2129 136. 2130 137. 2131 138. 2132 139. 2133 140. 2134 141. 2135 142. 2136 143. 2137 144. 2138 145. 2139 146. 2140 147. 2141 148. 2142 149. 2143 150. 2144 151. 2145 152. 2146 153. 2147 154. 2148 155. 2149 156. 2150 157. 2151 158. 2152 159. 2153 160. 2154 161. 2155 162. 2156 163. 2157 164. 2158 165. 2159 166. 2160 167. 2161 168. 2162 169. 2163 170. 2164 171. 2165 172. 2166 173. 2167 174. 2168 175. 2169 176. 2170 177. 2171 178. 2172 179. 2173 180. 2174 181. 2175 182. 2176 183. 2177 184. 2178 185. 2179 186. 2180 187. 2181 188. 2182 189. 2183 190. 2184 191. 2185 192. 2186 193. 2187 194. 2188 195. 2189 196. 2190 197. 2191 198. 2192 199. 2193 200. 2194 201. 2195 202. 2196 203. 2197 204. 2198 205. 2199 206. 2200 207. 2201 208. 2202 209. 2203 210. 2204 211. 2205 212. 2206 213. 2207 214. 2208 215. 2209 216. 2210 217. 2211 218. 2212 219. 2213 220. 2214 221. 2215 222. 2216 223. 2217 224. 2218 225. 2219 226. 2220 227. 2221 228. 2222 229. 2223 230. 2224 231. 2225 232. 2226 233. 2227 234. 2228 235. 2229 236. 2230 237. 2231 238. 2232 239. 2233 240. 2234 241. 2235 242. 2236 243. 2237 244. 2238 245. 2239 246. 2240 247. 2241 248. 2242 249. 2243 250. 2244 251. 2245 252. 2246 253. 2247 254. 2248 255. 2249 256. 2250 257. 2251 258. 2252 259. 2253 260. 2254 261. 2255 262. 2256 263. 2257 264. 2258 265. 2259 266. 2260 267. 2261 268. 2262 269. 2263 270. 2264 271. 2265 272. 2266 273. 2267 274. 2268 275. 2269 276. 2270 277. 2271 278. 2272 279. 2273 280. 2274 281. 2275 282. 2276 283. 2277 284. 2278 285. 2279 286. 2280 287. 2281 288. 2282 289. 2283 290. 2284 291. 2285 292. 2286 293. 2287 294. 2288 295. 2289 296. 2290 297. 2291 298. 2292 299. 2293 300. 2294 301. 2295 302. 2296 303. 2297 304. 2298 305. 2299 306. 2300 307. 2301 308. 2302 309. 2303 310. 2304 311. 2305 312. 2306 313. 2307 314. 2308 315. 2309 316. 2310 317. 2311 318. 2312 319. 2313 320. 2314 321. 2315 322. 2316 323. 2317 324. 2318 325. 2319 326. 2320 327. 2321 328. 2322 329. 2323 330. 2324 331. 2325 332. 2326 333. 2327 334. 2328 335. 2329 336. 2330 337. 2331 338. 2332 339. 2333 340. 2334 341. 2335 342. 2336 343. 2337 344. 2338 345. 2339 346. 2340 347. 2341 348. 2342 349. 2343 350. 2344 351. 2345 352. 2346 353. 2347 354. 2348 355. 2349 356. 2350 357. 2351 358. 2352 359. 2353 360. 2354 361. 2355 362. 2356 363. 2357 364. 2358 365. 2359 366. 2360 367. 2361 368. 2362 369. 2363 370. 2364 371. 2365 372. 2366 373. 2367 374. 2368 375. 2369 376. 2370 377. 2371 378. 2372 379. 2373 380. 2374 381. 2375 382. 2376 383. 2377 384. 2378 385. 2379 386. 2380 387. 2381 388. 2382 389. 2383 390. 2384 391. 2385 392. 2386 393. 2387 394. 2388 395. 2389 396. 2390 397. 2391 398. 2392 399. 2393 400. 2394 401. 2395 402. 2396 403. 2397 404. 2398 405. 2399 406. 2400 407. 2401 408. 2402 409. 2403 410. 2404 411. 2405 412. 2406 413. 2407 414. 2408 415. 2409 416. 2410 417. 2411 418. 2412 419. 2413 420. 2414

2nd Full Foot 1 and 4th Shaded Linotype

No. 3. *Stroph. Test. Lond.*—Den. *Stroph. Test. Lond.*

20

Crystal Controlled High Frequency Transistor Oscillators

W. F. CHOW*

Crystal controlled transistor oscillators of 10-50 mc frequency range were studied for their frequency stability with change of supply voltage and of temperature. Good frequency stability can be obtained from a properly designed transistor oscillator without the use of non-linear compensation techniques or the need for any temperature controlled chamber. Experimental results give a frequency change of 3.9 parts per million per 10% change of supply voltage, and a frequency change of only 0.22 part per million per degree centigrade of ambient temperature change.

[Tear sheets of this article are available on written request]

CRYSTAL CONTROLLED OSCILLATORS are used very often in communication equipments. Whether used as the master oscillator of a transmitter or as the local oscillator of a receiver, one of the essential functions of a crystal controlled oscillator is to produce a frequency of oscillation which is stable with changes of supply voltage and of ambient temperature. The oscillator circuit should be such that the frequency of oscillation is determined by the crystal only. Any change of the frequency with temperature should be contributed by the crystal, and if possible, other circuit elements should react to the change of temperature in such a way that the frequency change is compensated.

In vacuum tube circuitry, the above requirements of crystal controlled oscillation are met partly by circuits such as the Pierce, Miller, bridged T, Butler cathode coupled, transformer coupled oscillators, etc. The simplified circuit diagrams of these oscillators are shown in Figs. 1 to 5. Each circuit has its own limitations and a certain field of application. With a good quality crystal, a frequency stability of about $\pm 0.0015\%$ against the change of temperature from -60°C to $+100^{\circ}\text{C}$ can be achieved.

Since the properties of a transistor differ from those of a vacuum tube, it is often found that a transistor crystal controlled oscillator derived from a tube circuit does not give the stability desired. It is also found that some transistor circuits are not able to oscillate at the harmonic frequency of a crystal, especially in the vhf region. This article presents the results of a study of crystal controlled transistor oscillators, and the development of a new crystal controlled transistor oscillator.

Review of Some Commonly Used Crystal Controlled Transistor Oscillators

There are several commonly used crystal controlled transistor oscillators as shown in Figs. 6 to 9. The prin-

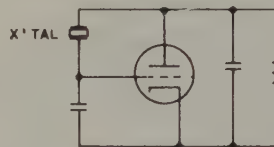


Fig. 1—Pierce oscillator



Fig. 2—Miller oscillator

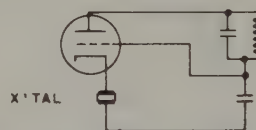


Fig. 3—Bridged T oscillator

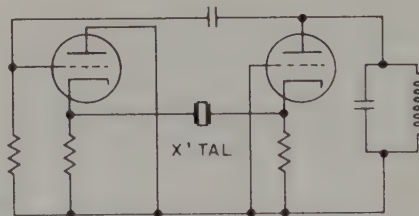


Fig. 4—Butler cathode coupled oscillator

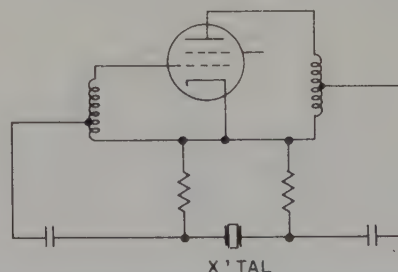


Fig. 5—Transformer coupled oscillator

*General Electric Company, Syracuse, N. Y.

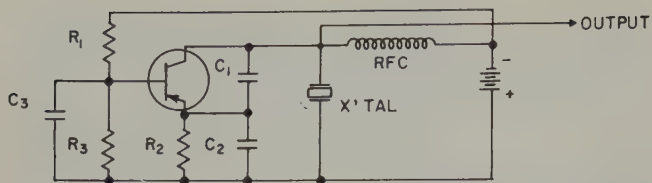


Fig. 6—Commonly used transistor oscillator No. 1

principles of oscillation of these circuits can be visualized as follows:

- (1) Fig. 6 shows a Clapp oscillator. Resistors R_1 and R_3 provide proper base bias. C_3 is an rf by-pass capacitor. R_2 provides the emitter $d-c$ path. C_1 and C_2 form a feedback circuit. The rfc is used in the collector bias voltage path. A resistance may be used in its place and is occasionally found to be better than the rfc as protection against spurious oscillations.

The crystal is operated at frequencies between its series resonant frequency and its parallel resonant frequency. Thus, a simplified $a-c$ equivalent circuit of the Clapp oscillator is shown in Fig. 10(a) and 10(b). The electrical characteristics of the crystal are represented by the series parallel network of C_p , C_s , r and L , as shown in Fig. 10(a). For frequencies between the series resonant frequency and the parallel resonant frequency, the network reduces to the one shown in Fig. 10(b) where

$$r' = \left[\frac{1}{r + \left(\omega L - \frac{1}{\omega C_s} \right)^2} \right] \quad (1)$$

and

$$\omega L_e = \left[\frac{1}{\left(\omega L - \frac{1}{\omega C_s} \right)^2 - \omega C_p} \right] \quad (2)$$

The equivalent circuit shown in Fig. 10(b) is the same as the familiar Colpitts oscillator. Therefore, the principle of oscillation is the same. Capacitor C_2 is usually one or two

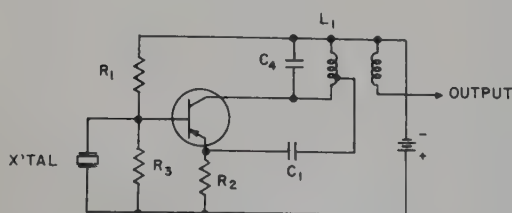


Fig. 8—Commonly used transistor oscillator No. 3

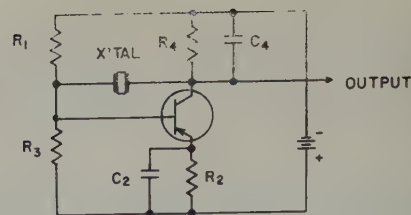


Fig. 7—Commonly used transistor oscillator No. 2

orders of magnitude larger than C_1 , and capacitor C_1 is usually one or two orders of magnitude larger than the collector to base junction capacitance of the transistor.

At 1 mc , a frequency stability of ± 2 ppm for $\pm 10\%$ supply voltage variation and 120 ppm for a temperature change of $-50^\circ C$ to $+80^\circ C$ can be achieved. This circuit is, however, less able to oscillate at higher frequencies. This is due to the phase shift between the emitter and the collector junctions. The feedback signal provided by capacitors C_1 and C_2 becomes out of phase as the frequency increases.

- (2) Fig. 7 shows a circuit similar to the Pierce oscillator shown in Fig. 1. Resistances R_1 , R_3 , and R_2 provide the $d-c$ bias for the base and the emitter. C_2 is an rf by-pass capacitor. Resistance R_4 provides the collector $d-c$ path and it also appears as part of the load, if small. Capacitance C_4 is used to obtain the proper phase relation.

The principle of oscillation of this circuit can be visualized in the simplified $a-c$ circuits shown in Figs. 11(a) and 11(b). The crystal is used at a frequency between its series resonant frequency and its parallel resonant frequency, and therefore it acts as an inductance. In Fig. 11(b), L_e is the equivalent effective inductance of the crystal. The position of L_e in the circuit is rearranged. The connection of inductance L_e to the base is marked "a," and is indicated by the dotted line. This rearrangement of circuit components makes it clear that the oscillation is produced by the feedback of the amplified signal into the base through the tank circuit L_e-C_4 , and the output capacitance of the transistor. With the feedback connection "a-a" open, the circuit shown in Fig. 11(b) can be easily recognized as a common

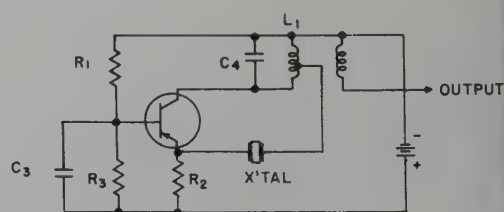


Fig. 9—Commonly used transistor oscillator No. 4

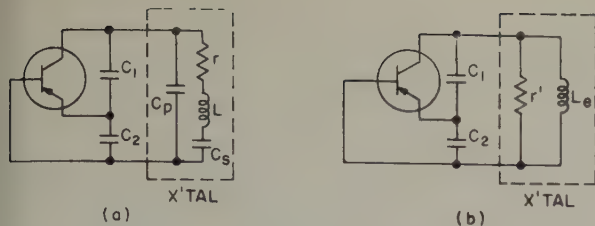


Fig. 10—Equivalent circuit of Fig. 6

emitter *rf* amplifier. The signal fed into the base terminal is amplified and the output is fed to the load at one end of the inductance L_e . Therefore the ability of this oscillator to oscillate at high frequencies is determined by the power gain of the common emitter circuit at high frequencies, and proper impedance transformation of the tank circuit.

- (3) Fig. 8 shows an oscillator having the crystal in the base circuit. Resistors R_1 and R_3 provide the base bias. R_2 provides the emitter *d-c* path. The feedback circuit consists of a tap on the inductance L_1 and capacitance C_1 . The crystal is operated in the series resonant mode. The amount of feedback through capacitance C_1 to the emitter is adjusted to such a small value that oscillation begins only when the crystal is series resonant. Thus, the simplified *a-c* equivalent circuits are as shown in Figs. 12 (a) and 12 (b). Since the loss resistance r of a crystal is usually very small, the circuit shown in Fig. 12 (b) is similar to the well-known Hartley oscillator. The control of the amount of feedback is accomplished through proper tapping of inductance L_1 . Capacitance C_1 blocks the collector bias voltage and is also used to obtain a certain amount of phase shift necessary to compensate for the internal phase shift of the transistor. Therefore, this circuit oscillates more readily at higher frequencies than the one shown in Fig. 6.

However, the frequency stability of this circuit is relatively poor. As the frequency increases, the reactance of the stray circuit capacitance across the crystal and the C_p of the crystal, becomes smaller. This circuit may oscillate at frequencies other than that of the crystal frequency.

- (4) Fig. 9 shows a circuit similar to the one in

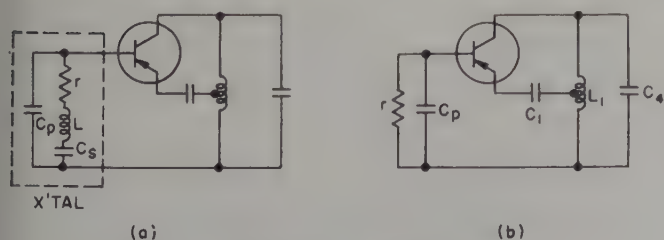


Fig. 12—Equivalent circuit of Fig. 8

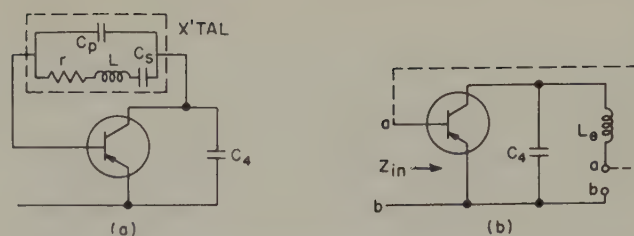


Fig. 11—Equivalent circuit of Fig. 7

Fig. 8 but having the crystal inserted in the feedback path, and the base by-passed to the ground by a capacitance C_3 . The crystal is again operated in its series resonant mode. Simplified *a-c* circuits are shown in Figs. 13 (a) and 13 (b). The frequency stability is also relatively poor. The tapping point of the feedback path is critical for good frequency stability. As the frequency increases, the reactance of the stray capacitance and the C_p of the crystal, becomes smaller. This circuit may also oscillate at frequencies other than that of the crystal frequency.

A New Crystal Controlled High Frequency Transistor Oscillator

Figure 14 shows a new crystal controlled transistor oscillator. Resistances R_1 , R_2 and R_3 provide the *d-c* bias for the base and the emitter. The load is connected to the secondary winding of the transformer T . Proper impedance transformation is provided by the transformer to step up the impedance of the load to the level of the primary winding.

The crystal is used at a frequency between its series resonant frequency and its parallel resonant frequency. Therefore, it appears as an inductance. Resistances R_1 , R_2 and R_3 are large and their *a-c* effects can be neglected. Figs. 15 (a) and 15 (b) show the simplified equivalent circuits of the oscillator. In Fig. 15 (b), L_e is the equivalent inductance given by Eq. (2). The equivalent loss resistance r' given by Eq. (1) is usually very large and is neglected here. R_L is the equivalent load resistance.

Using a simplified "T" equivalent circuit for the transistor as shown in Fig. 16, this oscillator can be analyzed as follows:

In Fig. 15 (b), the input impedance of the transistor at points "1-2" is

$$Z_{in} = h_{11} - \frac{h_{12} h_{21}}{h_{22} + Y_L} \quad (3)$$

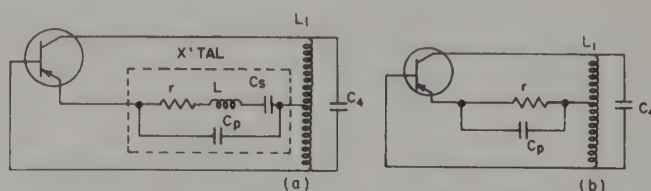


Fig. 13—Equivalent circuit of Fig. 9

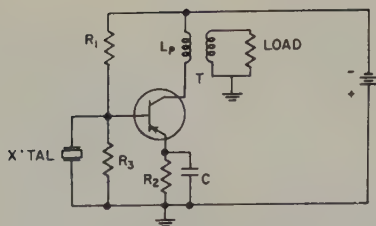


Fig. 14—A new crystal controlled high frequency transistor oscillator.

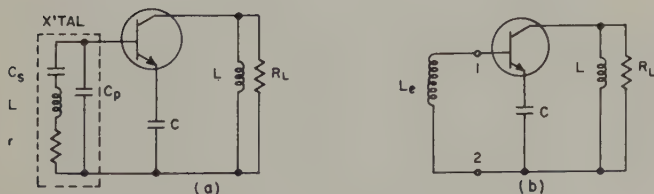


Fig. 15—Equivalent circuit of Fig. 14

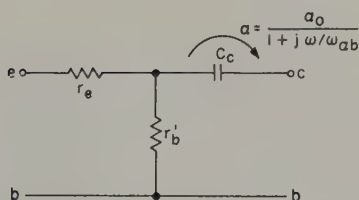


Fig. 16—Simplified transistor equivalent circuit

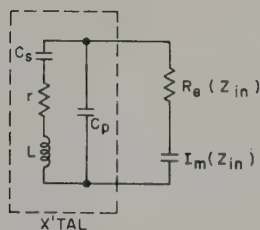


Fig. 17—Simplified equivalent circuit of Fig. 14

TABLE I

TRANSISTOR NO.	CRYSTAL FREQUENCY (PARALLEL RESONANT)	Δf	CRYSTAL FREQUENCY (SERIES RESONANT)	Δf	CRYSTAL FREQUENCY (PARALLEL RESONANT)	Δf
	27140.000 KC	CPS	33208.000 KC	CPS	46660.000 KC	CPS
1	27138.733	1267	33209.774	1774	46654.105	5895
2	27139.274	726	33210.395	2395	46655.127	4873
3	27138.745	1255	33209.796	1796	46654.492	5508
4	27138.745	1255	33209.690	1690	46654.279	5721
5	27138.846	1154	33209.881	1881	46654.715	5285
6	27139.142	858	33210.312	2312	46655.052	4948
7	27139.080	920	33210.224	2224	46654.895	5105
8	27138.721	1279	33209.703	1703	46654.022	5978

where

$$Y_L = \frac{1}{R_L} + \frac{1}{j\omega L} \quad (4)$$

and h 's are the two port h parameters of the transistor having a capacitor C in the emitter lead.

Since the input impedance Z_{in} is directly across the crystal, this oscillator circuit can be simplified further as shown in Fig. 17, where $R_e(Z_{in})$ and $I_m(Z_{in})$ are the real and imaginary components respectively. The conditions required to produce oscillation are that the real part of the input impedance must be negative and the loss of the crystal be small. The condition required to exclude the possibility of spurious oscillation is that the imaginary component of the input impedance must be capacitive. These conditions can be

met by a proper design of the ratio $\frac{C}{C_e}$ as derived in

the appendix. Thus $\frac{C}{C_e}$ should be within the boundaries set by two values obtained from Eq. (21).

$$\frac{C}{C_e} = \frac{(\omega_{ab}/\omega)^2}{2\omega_{ab} C_e r_b'} - 1 \pm \sqrt{\left[\frac{(\omega_{ab}/\omega)^2}{2\omega_{ab} C_e r_b'} - 1 \right]^2 - \left(\frac{\omega_{ab}}{\omega} \right)^2} - 1$$

For example, let

$$\frac{1}{\omega_{ab} r_b' C_e} = 3, \text{ and } \frac{\omega_{ab}}{\omega} = 2$$

The ratio $\frac{C}{C_e}$ should be $0.53 < \frac{C}{C_e} < 9.47$ and the

negative resistance reaches a maximum when $\frac{C}{C_e} = 0.9$. In order to insure a strong oscillation, the ratio of

$\frac{C}{C_e}$ should be about 0.9.

The equivalent capacitance of the input impedance is given by Equation (22) derived in the Appendix.

$$C_e = C_c \frac{1 + \left(\frac{\omega}{\omega_{ab}} \right)^2 \left(1 + \frac{C}{C_c} \right)^2}{1 + \left(\frac{\omega}{\omega_{ab}} \right)^2 \left(1 + \frac{C}{C_c} \right)} \quad (22)$$

For the above example $C_e \approx 1.29 C_o$. The frequency of oscillation is determined by the C_e of the input impedance and L_e of the crystal.

Experimental Study of the New Oscillator

The circuit used in the test is shown in Fig. 18. Eight G. E. germanium tetrodes 3N37 were used in the test. The bias point of the tetrodes was fixed at an emitter current $I_e = 1.8 \text{ ma}$, interbase bias $V_{bb} = -4 \text{ V}$, and collector bias voltage $V_c = 6 \text{ V}$.

Test (A). Three crystals were used to test the frequency deviation among transistors at room temperature and fixed bias supplies. The results are shown in Table I.

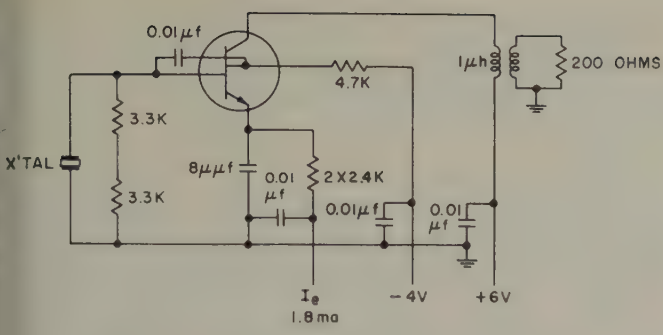


Fig. 18—Experimental oscillator circuit

At 27140.000 kc crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.004%. The average deviation of the actual frequency from the average of the actual frequency 27138.914 kc is 0.00053%.

At 33208.000 kc crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.0059%. The average deviation of the actual frequency from the average of the actual frequency 33209.971 kc is 0.00076%.

At 46660.000 kc crystal frequency, the average deviation of the actual frequency from the crystal frequency is 0.0116%. The average deviation of the actual frequency from the average of the actual frequency 46654.588 kc is 0.00078%.

Test (B). At room temperature, the frequency deviation due to the change of supply voltage was measured. The results are plotted in Fig. 19. A frequency change of 3.9 parts per million for a 10% change of supply voltage was found.

Test (C). The circuit shown in Fig. 18 was used in the temperature test. The bias supply voltage was kept constant. Both the crystal and the transistor were subjected to the variation of temperature. The results were plotted in Fig. 20. A typical "S" curve was found. For the temperature range of -30°C to +70°C the maximum frequency change was within 0.00096%. The temperature characteristic curve of the crystal used in the test is shown in Fig. 21.

Discussion

During the experimental study it was found that the value of capacitor C in Fig. 14 determined the range of frequency within which the circuit oscillated. A given crystal can be used and the circuit can be made to oscillate either at the fundamental frequency or at its odd harmonics simply by changing the capacitance C from a large value to a small value. This phenomenon is also indicated in Eq. 16 of the Appendix, which shows that the negative resistance is a

function of $\frac{C}{C_c}$ and $\frac{\omega}{\omega_{ab}}$.

Since inductance L_p in Fig. 14 was not tuned to resonate at the frequency of oscillation, and since it was also heavily loaded to give a poor Q , the change

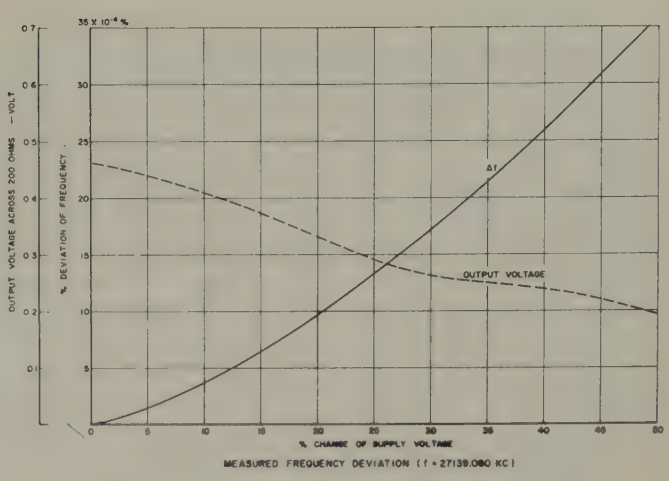


Fig. 19—Measured frequency deviation ($f = 27139.080$ kc)

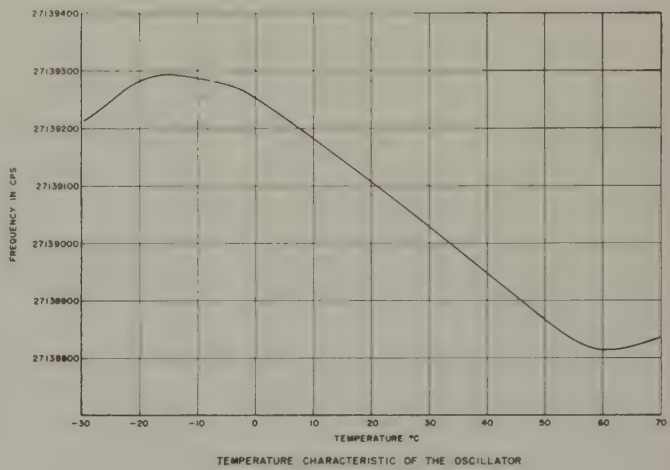


Fig. 20—Temperature characteristic of the oscillator

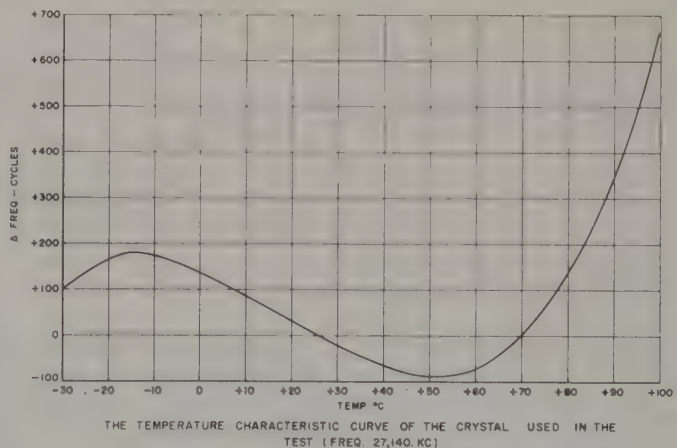


Fig. 21—Temperature characteristic curve of the crystal used in the test (Freq.-27,140. kc)

in frequency of oscillation was accomplished by changing only the crystal without any change or re-adjustment of circuit components. It was also found that if the oscillation was strong, harmonics of good

amplitude could be obtained by tuning L_p with a capacitance to the harmonic frequency. Thus, a frequency multiplying stage is not necessary for frequencies such as 150 or 200 mc, etc.

The experimental data show that the frequency stability of this new oscillator, shown in Fig. 14, is better than the other crystal controlled transistor oscillators discussed previously, and is also found to be better than that of most vacuum-tube circuits.

Acknowledgement

The author wishes to thank C. D. Aiken for his assistance in making the measurements.

References

1. Keorijian, E., "Stable Transistor Oscillator," *IRE Tran.*, CT-3, 38-44, March 1956.
2. Cheng, C. C., "Frequency Stability of Point Contact Transistor Oscillators," *Proc. IRE* 44, 219-223, February 1956.

APPENDIX

The h parameters of a common emitter transistor having a capacitor C in the emitter lead are:

$$h_{11} = \frac{\left(r_e + \frac{1}{j\omega C}\right) r_b' + \frac{1}{j\omega C_c} \left[\left(r_e + \frac{1}{j\omega C}\right) + r_b' (1 - \alpha)\right]}{\left(r_e + \frac{1}{j\omega C}\right) + \frac{1}{j\omega C_c} (1 - \alpha)} \quad (5)$$

$$h_{12} = \frac{r_e + \frac{1}{j\omega C}}{\left(r_e + \frac{1}{j\omega C}\right) + \frac{1}{j\omega C_c} (1 - \alpha)} \quad (6)$$

$$h_{21} = \frac{-\left(r_e + \frac{1}{j\omega C} - \frac{\alpha}{j\omega C_c}\right)}{\left(r_e + \frac{1}{j\omega C}\right) + \frac{1}{j\omega C_c} (1 - \alpha)} \quad (7)$$

$$h_{22} = \frac{1}{\left(r_e + \frac{1}{j\omega C}\right) + \frac{1}{j\omega C_c} (1 - \alpha)} \quad (8)$$

In a practical circuit $\left|\frac{1}{j\omega C}\right| \gg r_e$. Therefore

$$\begin{aligned} h_{11} &\cong \frac{\frac{r_b'}{j\omega C} + \frac{1}{j\omega C_c} \left[\frac{1}{j\omega C} + r_b' (1 - \alpha)\right]}{1/j\omega C + \frac{(1 - \alpha)}{j\omega C_c}} \\ &\cong \frac{r_b' + \frac{C}{C_c} \left[\frac{1}{j\omega C} + r_b' (1 - \alpha)\right]}{1 + \frac{C}{C_c} (1 - \alpha)} \end{aligned} \quad (9)$$

and

$$\frac{h_{12}h_{21}}{h_{22} + Y_L} \cong \frac{-\left(\frac{1}{j\omega C} - \frac{\alpha}{j\omega C_c}\right)}{1 + (1 - \alpha) \frac{C}{C_c} + j\omega CY_L \left[\frac{1}{j\omega C} + \frac{1 - \alpha}{j\omega C_c}\right]^2} \quad (10)$$

Using the relations:

$$\alpha = \frac{\alpha_0}{1 + j\omega/\omega_{ab}} \quad (11)$$

$$(1 - \alpha_0) \ll \frac{\omega}{\omega_{ab}} \quad (12)$$

and

$$\frac{C}{C_c} (1 - \alpha_0) \ll 1 \quad (13)$$

The real component of the input impedance Z_{in} is

$$R_e(Z_{in}) = r_b' - \frac{\frac{C}{C_c} \frac{1}{\omega_{ab} C_c}}{1 + \left[\frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \right]^2} + R_e \left[\frac{h_{12} h_{21}}{h_{22} + Y_L} \right] \quad (14)$$

where $R_e \left[\frac{h_{12} h_{21}}{h_{22} + Y_L} \right]$ is the real part of the term $\frac{h_{12} h_{21}}{h_{22} + Y_L}$.

The imaginary component of Z_{in} is

$$I_m(Z_{in}) = j \frac{-\frac{1}{\omega C_c} - \frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \frac{1}{\omega_{ab} C_c}}{1 + \left[\frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \right]^2} + I_m \left[\frac{h_{12} h_{21}}{h_{22} + Y_L} \right] \quad (15)$$

Where $I_m \left[\frac{h_{12} h_{21}}{h_{22} + Y_L} \right]$ is the imaginary part of the term $\frac{h_{12} h_{21}}{h_{22} + Y_L}$.

If Y_L is large and the term $\frac{h_{12} h_{21}}{h_{22} + Y_L}$ can be neglected, then, as the first approximation,

$$R_e(Z_{in}) \cong r_b' - \frac{\frac{C}{C_c} \frac{1}{\omega_{ab} C_c}}{1 + \left[\frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \right]^2} \quad (16)$$

and

$$I_m(Z_{in}) \cong j \frac{-\frac{1}{\omega C_c} - \frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \frac{1}{\omega_{ab} C_c}}{1 + \left[\frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \right]^2} \quad (17)$$

Since this input impedance Z_{in} is directly across the crystal as shown in *Fig. 17* a negative resistance must exist in order to produce oscillation. Thus, from Equation (16)

$$\frac{C}{C_c} \frac{1}{\omega_{ab} C_c} > r_b' \left[1 + \left(\frac{\omega}{\omega_{ab}} \right)^2 \left(1 + \frac{C}{C_c} \right)^2 \right] \quad (18)$$

In order to find the range of $\frac{C}{C_c}$ with which the negative resistance exists we set

$$\frac{C}{C_c} \frac{1}{\omega_{ab} C_c} = r_b' \left[1 + \left(\frac{\omega}{\omega_{ab}} \right)^2 \left(1 + \frac{C}{C_c} \right)^2 \right] \quad (19)$$

or

$$\left(\frac{C}{C_c} \right)^2 + \left[2 - \frac{(\omega_{ab}/\omega)^2}{\omega_{ab} C_c r_b'} \right] \left(\frac{C}{C_c} \right) + \left(\frac{\omega_{ab}}{\omega} \right)^2 + 1 = 0 \quad (20)$$

solving for $\frac{C}{C_c}$, we have

$$\frac{C}{C_c} = \frac{(\omega_{ab}/\omega)^2}{2\omega_{ab} C_c r_b'} - 1 \pm \sqrt{\left[\frac{(\omega_{ab}/\omega)^2}{2\omega_{ab} C_c r_b'} - 1 \right]^2 - \left(\frac{\omega_{ab}}{\omega} \right)^2 - 1} \quad (21)$$

The frequency of oscillation can be calculated from the reactive component of Z_{in} given by Eq. 17 and the equivalent inductance L_e of the crystal as given by Eq. (2). The equivalent capacitance, C_e , is given by

$$C_e = C_c \frac{1 + \left[\frac{\omega}{\omega_{ab}} \left(1 + \frac{C}{C_c} \right) \right]^2}{1 + \left(\frac{\omega}{\omega_{ab}} \right)^2 \left(1 + \frac{C}{C_c} \right)} \quad (22)$$

This equivalent capacitance C_e is in series with the equivalent inductance L_e of the crystal. The frequency of oscillation is slightly below the parallel resonant frequency of the crystal.

Resistivity Measuring Techniques In Semiconductors*

H. GUNTHER RUDENBERG**

This article describes the development and design of direct reading apparatus for resistivity measurements. Various methods of conductive, capacitive and inductive connection to the semiconductor were investigated. For small samples or localized measurements in germanium and silicon, conductive four point probes in a square array are utilized. Spurious rectification at the point contacts and high probe resistances are avoided by the use of a small forward-biasing direct current which stabilizes the series resistance of the probes. Best results have been obtained with small *a-c* measurements using a tuned detector. In *d-c* measurements with a potentiometer or electrometer, forward bias of both voltage probes is assured by proper placement of impedances and shielding all sources of reverse leakage. Thus, resistivities of 1000 ohm-cm may readily be measured with proper surface preparation of the sample and low enough signals to avoid errors from injection effects. A calibration standard using thin silicon slices with alloyed ohmic contacts is used to check the absolute accuracy of the equipment. The apparatus described can be used to measure the surface sheet resistance of diffused layers, and the bias current here isolates this layer electrically from an opposite polarity substrate. Accuracies of 5 to 10% in the range of 0.01 to 1000 ohm-cm are obtainable.

[Tear sheets of this article are available on written request]

MEASUREMENT of resistivity of semiconductors is commonly used in preference to Hall effect measurements⁽¹⁾ for the evaluation of semiconductor doping, both in research and in manufacturing control. From a knowledge of the resistivity ρ and the effective carrier mobility⁽²⁾, μ , one may obtain the carrier or doping level, N , from

$$N = \frac{1}{e \mu \rho}$$

where e is the electronic charge. This doping level is of importance in controlling voltage and capacitance of semiconductor devices. Similarly in the design and manufacture of diffused devices, the surface resistance⁽³⁾ of such layers is an important parameter. Changes of resistivity in heat treating, nuclear bombardment and temperature can occur and often must be monitored.

Apparatus useful in plant and laboratory for such measurements should be simple, require a minimum of sample preparation, preferably be non-destructive, and be useable on production pieces rather than on specially made shapes. Various methods known or described in the literature were compared for their range, ease of use and of calibration, and equipment simplicity. It was desired to measure a wide range of silicon and germanium parts, and hoped that the ap-

paratus would be useful with such new materials as silicon carbide and other intermetallic semiconductors.

As most ordinary contacts to semiconductors give rise to high impedance surface barriers, which would affect the results, the sample resistance cannot generally be measured by applying two probes from an ohmmeter. Probe impedances must be carefully accounted for or their effects minimized and even avoided. Thus the use of separate current and voltage connections leading to a four point probe⁽⁴⁾ arrangement are common. In a different approach capacitive⁽⁵⁾ or conductive⁽⁶⁾ excitation of a current in the semiconductor sample have been described to overcome probe effects. These various methods of coupling to the semiconductor are reviewed for their suitability for this apparatus. Many of the techniques developed for the determination of ground current and earth resistance are useful here.

Conductive Connection Techniques

A technique which minimizes the effects of resistive barriers at the semiconductor consists of cutting sample of special shape and using separate current and voltage leads (Fig. 1). To further reduce the effects of contact resistance, wide contact areas⁽⁷⁾ are used, much wider than the main sample, and these are sandblasted and electroplated. Measurements are made of the voltage between the inner contacts due to a known current impressed through the outer two contacts. This is the most accurate technique developed, but it has the disadvantage of requiring the cutting and fabrication of a special sample from each semiconductor piece under study.

* Presented at the 1958 National Electronics Conference, Chicago, Ill., Oct. 13-15 1958

**Transitron Electronic Corporation, Wakefield, Massachusetts

A useful alternative is the so-called "one probe" method, where a single traveling voltage probe is used to find the voltage change with position along a uniform sample stick, and from this the resistivity profile is evaluated (Fig. 2).

A further simplification derives from the recent developments of so-called ohmic alloyed contacts. Such contacts may be alloyed onto the sample, providing extremely low contact resistances of fractions of an ohm to a rectangular bar of semiconductor material of known dimensions. This allows the measurement of the bar resistance on an ohmmeter or a bridge. In the method adopted for calibration of the instrument to be described, a slice of germanium or silicon has such contacts alloyed one half inch apart (Fig. 3) and the piece is then cut off to one half inch width. The thickness w is measured with a micrometer and the sample resistance calculated from the measured sheet resistance by the relation

$$\rho = R_s w$$

Contacts are gold-antimony for n type material and gold-gallium for p type material to obtain negligible contact resistance. The advantage of this technique is that it uses slices and contacts similar to those used in device manufacture. The only drawbacks are the sample fabrication, and the possibility of affecting the resistivity by heat treatment during alloying at 500°C.

It must be remembered that the four probe technique minimizes the effects of current probe impedance, but still necessitates the use of a high impedance current source and a voltmeter or potentiometer of much higher impedance than the probes to avoid large errors.

The high impedance voltage measurements have been made both with d -c using a potentiometer or electrometer, and with a -c by means of an audio frequency current impressed through the sample and a tuned high impedance voltmeter connected to the voltage probes. In the latter case stray capacitances must be avoided so as to keep the impedances high.

Contactless Measurements

A capacitive coupling method has been described for completely avoiding contact resistance, and applied to a two-terminal measurement⁽⁵⁾ (Fig. 4).

Two collars of metal foil replace the probes, and a high enough radio frequency is used so that any contact resistance is completely shunted by the contact capacitance. Measurement of the impedance of the sample provides a resistance term which is the sample resistance, from which the resistivity is readily computed. This method is especially useful in the measurement of very high resistivity materials in excess of a hundred ohm centimeters, and to long uniform bars or crystals. It so happens that the commercial impedance bridge which is most suitable for these measurements is direct reading in terms of a parallel equivalent circuit, thus requiring additional

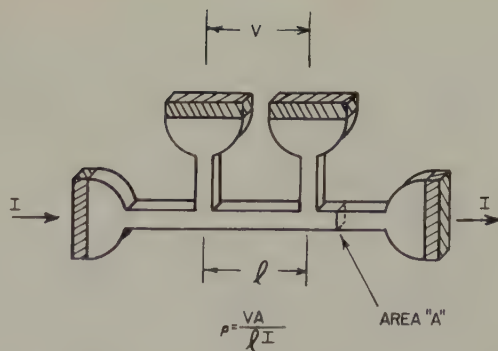


Fig. 1—Resistivity "bridge" shaped sample.

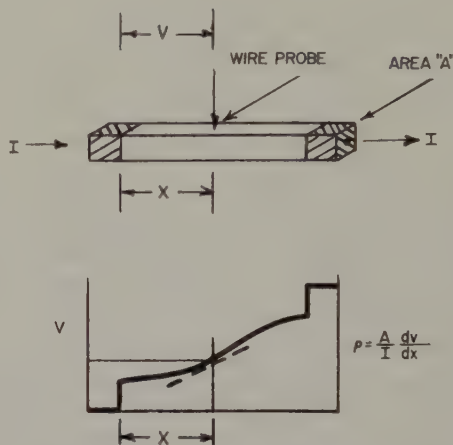


Fig. 2—The "One Probe" method.

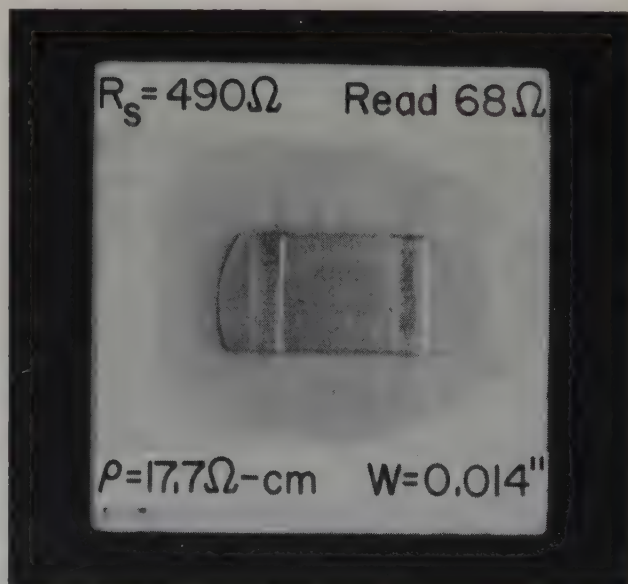


Fig. 3—Silicon standard sample slice.

computations to obtain the equivalent series resistance. A useful frequency of operation is one megacycle, using a General Radio Twin-T Impedance Bridge and a shielded radio receiver as detector. The technique is well suited for measuring the average resistivity of special silicon crystals, where the computations involved are justified.

An inductive method⁽⁶⁾ is also possible, and applications of this have been developed. The principle consists of inducing a circulating current from an adjacent coil into the surface of the semiconductor (Fig. 5) and determining the resistivity from the back *emf* induced in that coil from the circulating current. It is most suitable to measuring the lowest resistivities of semiconductors, and a similar method has been used for metals to determine plating material thickness or conductivity.

Difficulties lie in the narrow range of resistivities accurately measurable with any one coil, and the fact that exact calculation is difficult. Thus empirical calibrations are resorted to, which still require initial measurements by other techniques.

Four Point Probe Methods

Although the contactless methods are very elegant, their narrow range and more elaborate instrumentation restricts their usefulness. Experience with the four point method had demonstrated its simplicity, and had indicated that considerable improvement in range and accuracy might be obtained from a careful study of the contact resistance problem. An *a-c* instrument⁽⁸⁾ had been available for some time, (Fig. 6). This consisted of a low impedance 1000 cycle oscillator, a switched set of series resistors, and a tuned 1000 cycle vacuum tube voltmeter of moderate input impedance. Isolation transformers in both oscillator output and voltmeter input circuits provided the necessary balancing of signals to drive the symmetrical four-probe circuit. Adjustment of current was obtained by switching it through a standard resistor prior to the measurement.

The generator is a Neucor DK1 1000 cps oscillator and the tuned voltmeter is a standard Hewlett Packard 415B variable gain voltage indicator, having the meter scale replaced by one with a linear voltage scale (Fig. 7).

This system had given excellent service with germanium resistivity measurements, and for low and medium resistivity silicon material. The apparatus is built up in four blocks, the purchased oscillator and voltmeter, the transformer-resistor switching box and the probe unit. The latter has been designed to provide a constant spacing of one millimeter between adjacent probes with sufficient (5%) accuracy, otherwise variations of probe spacing would affect the resistivity readings. Probes are of hard material, such as tungsten or carbide, and are held in an insulating⁽⁹⁾ nylon or Kel-F block (Fig. 8), with only the tip of each probe protruding. Thus excessive pressure on

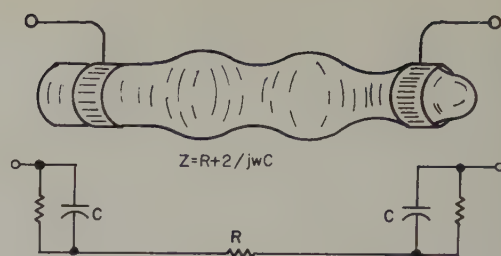


Fig. 4—Capacitive connections.

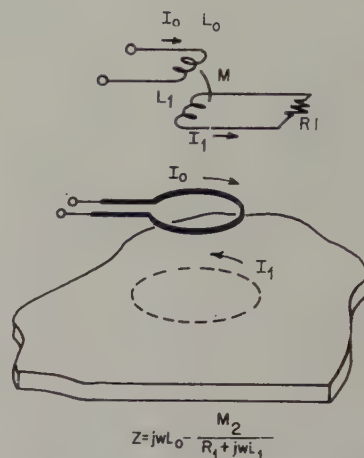


Fig. 5—Inductive method.

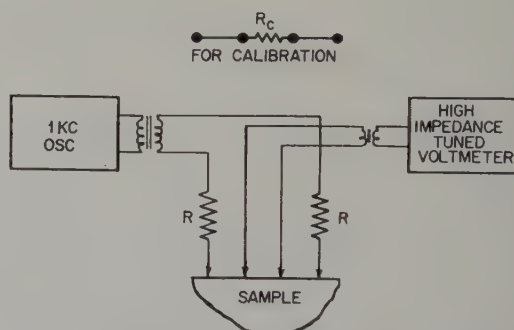


Fig. 6—Diagram of "Four-Probe" method.

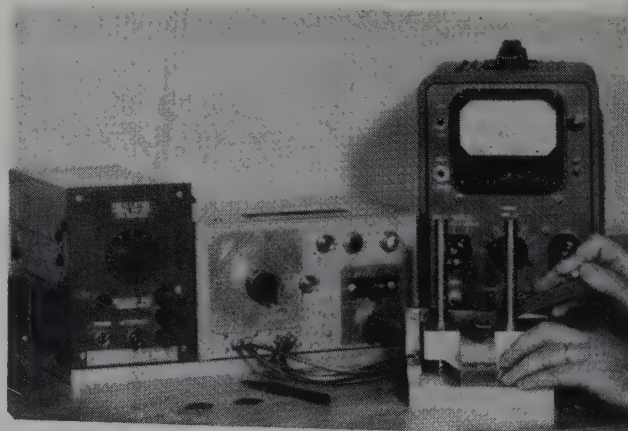


Fig. 7.—Photo of complete apparatus.

the spring-loaded probes would only bring the resilient insulating block down on the sample, preventing damage to the sample by excess needle pressure.

Normally probes are an "in-line" array⁽¹⁰⁾ but for many measurements on small samples a square array is used (Table I). This has the advantage of a smaller total extent of the fringing fields around the probes for the same probe spacing, but has only half the sensitivity of the linear probe array. Nevertheless, with a 40 mil square array, a 1/8 inch diameter semiconductor pellet may be measured with fair accuracy, which could hardly be done with an in-line array of four probes spaced 40 mils each.

Probe contact resistances are minimized by measuring resistivity on freshly lapped surfaces. In addition, probe points are kept sharp and a force of 1 to 2 pounds is applied to the four-probe array by means of springs to provide pressure of the probe tips against the sample.

Although initially satisfactory, increased resistivities now obtained with silicon have lately required further improvements, so that a method to lower probe contact resistances was developed.

Current Injection And Probe Resistance

A plot of the current-voltage characteristic of a point contact on a semiconductor surface illustrates the well known diode curve (Fig. 9). At low inverse and forward currents this consists of the contact leakage resistance and saturation current, and the junction voltage drop is given by the Schottky relation.

$$I = I_o (\exp \alpha V - 1)$$

This leads to the differential resistance or slope of the curve

$$R = 1/\alpha (I + I_o)$$

The factor $1/\alpha$ is usually 25 millivolts, although point contacts often show other values. For a good semiconductor or a true surface barrier this is 25,000 ohms for 1 microampere of forward current, and silicon saturation currents may be even lower, with still higher resistances. Thus for reverse currents ($I = -I_o$) the contact junction resistance is extremely high, and at zero current it is still appreciable. The contact resistance would be lowered to quite reasonable values at a forward current of a milliampere. At larger forward currents, the so-called spreading resistance of the contact must be added, given by Fig. 10.

$$R_s = \frac{\rho}{2\pi d} \text{ (round contact), or } R_s = \frac{\rho}{4d} \text{ (flat contact)}$$

where d is the diameter of the contact area touching the semiconductor surface, and ρ its resistivity. For a reasonable point diameter (0.04 mil or 10^{-4} cm) and 100 ohm-cm resistivity this is an appreciable spreading resistance of 150,000 ohms.

It is readily apparent that the junction resistance may be reduced to any desired value by injecting a

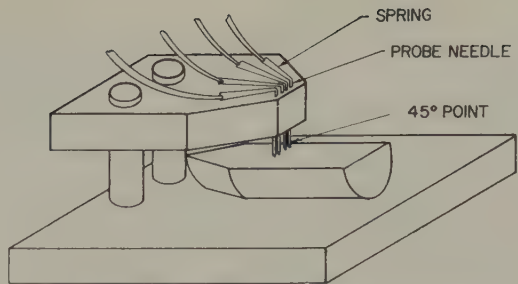


Fig. 8—Four-point probe assembly.

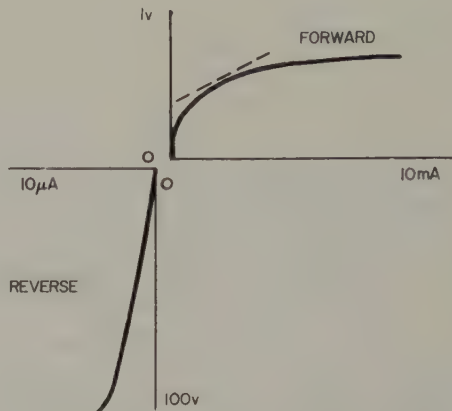


Fig. 9—Diode curve of probe point.

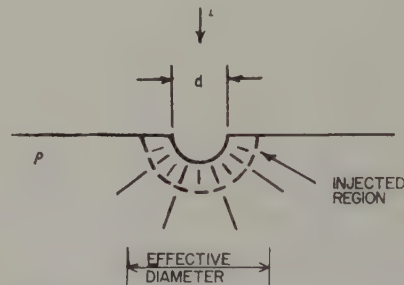


Fig. 10—Spreading resistance and injection.

forward current through the probe, and that a few microamperes are sufficient to reduce this resistance well below a few thousand ohms so as to have negligible effect on the measurements. Fortunately in many cases one may obtain a lowering of the spreading resistance portion of the contact resistance by the same current. This is due to the injection of minority carriers into the semiconductor, which lowers its effective resistance locally under the point. Naturally, too large an injected current would flood the space between probes with sufficient additional charges so as to lower the overall resistivity, leading to erroneous measurements. Nevertheless, by proportioning the injecting current (Fig. 10) so that the extent of the region of low resistance under each probe is much smaller than the probe spacing, say about one mil diameter, one can obtain a 25 fold reduction from the spreading resistance of our example. This condition

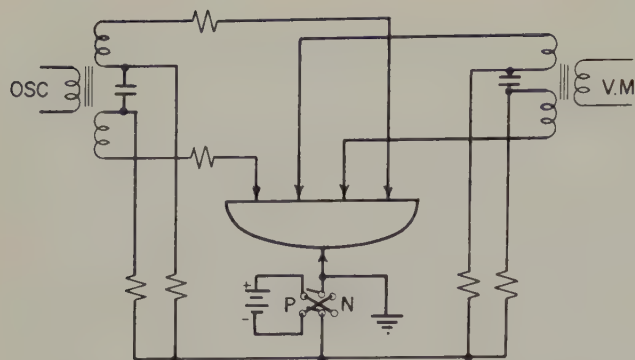


Fig. 11—A. C. measurement with forward bias.

sets an upper limit to the injecting current. For example, the limit is 10 microamperes for 100 ohm-cm material, leaving a junction resistance of 2,500 ohms and a spreading resistance of 6,500 ohms, totaling less than 10,000 ohms. Such contact resistance would be sufficiently low compared to any reasonable transformer and voltmeter input impedance as to be readily neglected.

Should the probe contacts be only slightly injecting, or the lifetime of carriers in the semiconductor be very short, much larger currents could be used and would be required to lower the junction and spreading resistances. In fact, the resistivity readings may be monitored to determine the value of current at which heating or injection effects affect the results. Fortunately it is the high resistivity material, such as silicon, that has the longest carrier lifetime; and it is here that the technique of controlled current injection is most needed and also most applicable.

The current injection is readily accomplished by superimposing upon the *a-c* probe current a small *d-c* current, (Fig. 11). Now a fifth contact is needed to the sample, to return these currents. Either an extra probe on the upper side of the sample or the ground-plate supporting the sample have been used equally successfully for this added connection. A considerable voltage may be needed to obtain the small injecting forward current through the probes, as this fifth contact is back-biased to the semiconductor sample. A considerable voltage barrier exists and must be overcome at this extra contact. Naturally, the current direction is reversed for samples of opposite polarity type.

A similar analysis is applicable to the *d-c* operated apparatus (Fig. 12). Here the direct current enters the sample by one and leaves by the second current probe, so that one of these is forward and the other reverse biased. The voltage difference between the two voltage probes then provides the measurement from which the resistivity is evaluated. Now it is seen from the probe characteristic (Fig. 9) that a small leakage current, say one microampere, in the forward direction will only displace the forward voltage drop by a very small amount. But a similar reverse cur-

rent could swing the floating probe voltage in the inverse direction by 10 to 100 volts. Thus it is important that no leakage current (60 cycle *a-c* included) ever brings the voltage probes into their inverse characteristic. This is ensured in this apparatus by applying small, equal forward currents to both voltage probes, or at least connecting equal high resistances from these probes to the forward-biased one of the current probes. All leakage currents from the reverse-biased current probe and from that side of the voltage supply and of the probe assembly must be avoided. This may be accomplished by placing a guard-ring or grounded shield around the wiring from that side. It must be remembered that voltages of several hundred volts may exist between that probe and the semiconductor surface, and that this could otherwise cause considerable leakage of current.

Other methods of carrier injection had been tried to move the probe characteristic to a low resistance region. Light and heat are both suitable, but not as useful, as their effect does not decay away from the probes like the injected current does. Injection of extra carriers due to light, however, has the advantage that the fifth contact is now biased in the forward direction by the light-generated return current, so that all probes have a low contact resistance.

Sample Size Corrections And Diffused Layers

The applications of this apparatus are greatly increased by its ability to provide measurements of the resistivity, not only of bulk samples or crystals, but also of slices and moderate size dice of diode and transistor parts. The change in readings to be expected when using samples of small dimensions has been calculated and presented for the in-line probes.⁽¹⁰⁾ For a square probe array similar computations may be made. The values for thick and thin

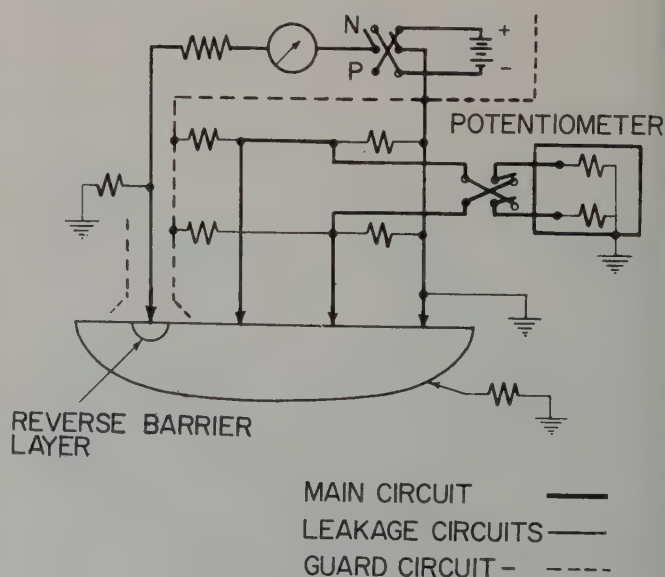


Fig. 12—D. C. measurement with guard circuit.

samples areas are presented in Table I. Most of the work described here involves measurements on thin slices, where either type of probe essentially reads the effective sheet resistance. Where an apparatus is initially designed and calibrated to be direct reading in resistivity for a large (semi-infinite) crystal, a correction curve⁽⁴⁾ shows the calibration value or reduction in input current to be used to obtain a direct reading of resistivity for a given wafer thickness. Conversely calibration may be made to make the apparatus direct reading on sheet resistance, necessitating a correction⁽¹¹⁾ when layer thicknesses exceed the probe spacing. These curves are presented in Fig. 13.

Sheet resistance readings on diffused layers are also readily taken. Diffused surface layers on one or both sides of a similar polarity substrate wafer add to the sheet conductivity of the wafer, so that (Fig. 14-A)

$$1/R_s = 1/R_{s0} + 1/R_D \text{ (or } + 2/R_D \text{)}$$

where R_D is the sheet resistance of the diffused layer and R_{s0} the original measured sheet resistance of the thin wafer. A more accurate calculation might have to be applied to thick wafers. In case the diffused layer is of opposite polarity from that of the substrate wafer, a p - n junction (Fig. 14B) effectively isolates the substrate and the other side from the measuring circuit. This is especially noticeable in the case of the apparatus described here with a bias current, which reverse biases such a diffused junction. Only occasionally are exceptions noticed when evaluating very shallow diffusion runs. In fact with good diffusion runs the bias return contact must be made directly to the diffused layer, as the junction to the substrate may block the bias current completely.

The relationship between diffusion depth, surface concentration and the resulting sheet resistance of the diffused layer is known⁽³⁾; suffice it here to say

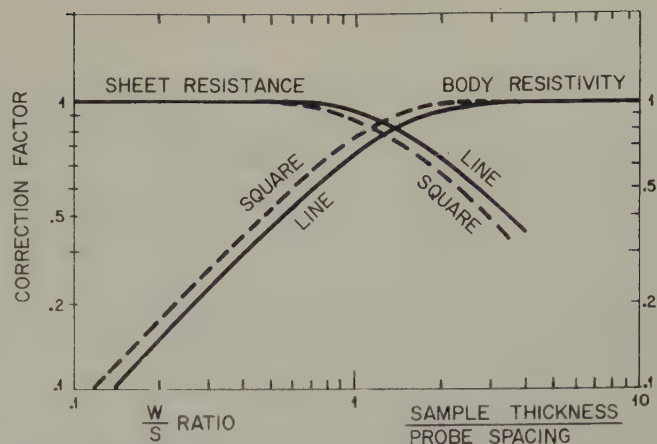


Fig. 13—Correction curves for thin slices.

that the sheet conductance $1/R_s$ is a direct measure, with an average carrier mobility μ , of the total number of dopant atoms, M , diffused per unit area into the surface,

$$1/R_s = e \mu M$$

determined by the product of surface concentration and diffusion depth. When adjusted to read sheet resistance, this apparatus is used for diffusion control.

Calibration and Accuracy

To make the apparatus direct reading the current in the appropriate equation (Table I) is adjusted to produce a unity voltage scale reading for a given value of resistivity. This is done by choice of the calibrating resistor. During "calibration," (Fig. 6), the current flows through the comparison resistor and is read on the same voltmeter so that $IR_c = V_c$. Thus a full scale reading of 1 ohm-cm is obtained when the current has been adjusted to give the same full-scale voltage reading across an R_c of 1.6 ohms with in-line probes of 0.1 cm spacing.

The sheet resistance readings are obtained by dividing the "resistivity" readings by 7.2. Alternately, a calibrating resistor of 0.11 ohms would make the apparatus "direct" reading in sheet resistance with

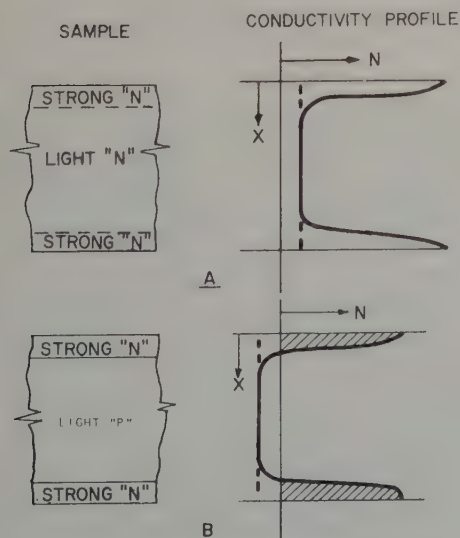




Fig. 14—Diffused surface layers.

TABLE I		
RESISTIVITY FORMULAE		
PROBES		
SAMPLE		
THICK CRYSTAL	$\rho = 2\pi s V/I$ $= 6.28s V/I$	$\rho = 2\pi s V/1.203I$ $= 5.23s V/I$
THIN SLICE w	$\rho_w = 4.53w V/I$	$\rho_w = 9.07w V/I$
RATIO, $\rho_w/\rho\infty$	0.72 w/s	$= 0.85w/s$
SHEET RESISTANCE	$R_s = 4.53 V/I$	$R_s = 9.07 V/I$

square probes, or 0.22 ohms for in-line probes of 0.1 cm spacing.

An assumption underlying the design of the instrument is that the initially set current is actually flowing through the sample under test. This may be ensured in the *d-c* instrument by monitoring this current with a meter. In the *a-c* version this is not easily done, so that the accuracy of this assumption is enhanced by using fairly high series resistance in the current supply, ten times larger than the highest expected series resistance of the current probes. This is why it is important to reduce their contact resistance also. In addition, checks are run with sample slices (Fig. 3) of high resistivity, having had their resistivity determined by the methods described previously. This checks instrumental errors, errors in probe alignment and problems of contact resistance. As increased contact pressure and current also lowers contact resistance, the reproducibility of readings to such changes as well as their accuracy within 5 percent on accurately known samples is taken as confirmation of the reliability of this apparatus. Probe needles eventually lose their sharp points, and needle replacement usually will correct any deterioration of performance. Thus the apparatus has given 5 percent accuracy up to 100 ohm-cm in silicon and 20% to 1000 ohm-cm with more careful surface lapping and cleaning. It has actually been used to measure the resistivity of etched germanium samples. Some care to avoid stray capacitance effects, and shielding and balancing of leads is necessary for the highest resistivity readings.

For measuring very low resistivities, the *a-c* apparatus must have the push-pull circuits carefully balanced, again to avoid stray direct coupling. Here a two-probe method and *d-c* measurements are very satisfactory; one must only take care that the current through the sample does not heat it too much. Probe resistance and injection effects are small, and do not limit performance.

It must be remembered that the voltage difference across the probes is quite minute. Taking the current amplitude to minimize injection at 10 milliamperes for 100 ohm-cm, a 0.1 centimeter spacing of linear

probes gives 1.5 millivolts full scale. Using the *a-c* technique with *d-c* injection, the *a-c* signals should be ten times less, or 150 microvolts. On the other hand, stray signals and direct feedthrough come from 1 volt levels, so that considerable care is necessary to obtain good performance. Spurious rectification at the probe from 60 cycle signals is not to be underestimated. It will not directly affect the *a-c* amplifier tuned, say, to 1000 cycles, but it may bias the probe contact into a region of high resistance.

Conclusion

Some of the problems encountered in making reasonably accurate routine resistivity measurements of semiconductors have been presented. Contactless measuring techniques have been reviewed, and a novel method of lowering probe contact resistance by forward current injection described. This has led to the development of a simple measuring apparatus covering a wide range of resistivity with reasonable accuracy. Normally in-line probes are used, but for small pieces and for checking uniformity of resistivity over a slice the square array probes are preferred because of their smaller extension.

In germanium the full range of magnitude from very low to intrinsic resistivities are readable. In silicon the upper limit of the *a-c* apparatus is near 1000 ohm-cm as presently built, and higher ranges are being measured with a carefully shielded *d-c* apparatus. On these highest ranges, surface preparation of the sample, such as lapping and cleaning in hot caustic, are essential. For silicon carbide at room temperature, some difficulties are encountered above several ohm-cm. However, a set of probe supports of Kel-F and one of Lava ceramic have been used and the sample measured at various elevated temperatures on top of a hot-plate. Thus silicon-carbide samples can be determined.

Acknowledgement

The author is grateful to many Transitron associates who have stimulated this work. The original *a-c* measuring apparatus was due to N. deWolfe and the square array probe to E. Simon.

References

- (1) W. Shockley—"Electrons and Holes in Semiconductors" Van Nostrand—p 215; 1950
- (2) G. Backenstoss—"Conductivity Mobilities of Electrons and Holes in Heavily Doped Silicon," *Phys. Rev.* 108, p 416; 1957
M. B. Prince—"Drift Mobilities in Semiconductors I-Ge" *Phys. Rev.* 92, p 681; 1953
- (3) G. Backenstoss—"Evaluation of the Surface Concentration of Diffused Layers in Silicon," *Bell System Tech. J.* 37, p 699; 1958
- (4) L. Valdes—"Resistivity Measurements on Germanium for Transistors," *Proc. I.R.E.* 42, p 420; 1954
- (5) I. R. Weingarten and M. Rothberg—"Methods of Measurement of Lifetime and Resistivity of Silicon Without Contacts" Presented at Electrochemical Society Semiconductor Symposium, Spring, 1958
- (6) H. K. Henisch and J. Zucker—"Contactless Method for the Estimation of Resistivity and Lifetime of Semiconductors," *Rev. Sci. Inst.* 27, p 409; 1956
- (7) Ref. 1 Frontispiece
- (8) L. P. Hunter—"Handbook of Semiconductor Electronics" McGraw-Hill—p 204; 1956
- (9) A. L. MacDonald, J. Soled and C. A. Stearns—"Four Probe Instrument for Resistivity Measurements of Germanium and Silicon," *Rev. Sci. Inst.* 27, p 409; 1956
- (10) A. Uhler, Jr.—"The Potentials of Infinite Systems of Sources and Numerical Solutions to Problems of Semiconductor Engineering," *Bell System Tech. J.* 34, p 105; 1955
- (11) F. M. Smits—"Measurement of Sheet Resistivities With the Four-Point Probe," *Bell System Tech. J.* 37, p 711; 1958

Alloying With Controlled Spreading in Silicon Transistors*

Part 2

J. ROSCHEN† T. J. MILES† C. G. THORNTON†

Surface spreading of the electrodes in silicon alloy transistors greatly affects the performance and uniformity of the device characteristics. With conventional radiant alloying techniques and low edge dislocation density silicon, electrode areas may increase more than 100 percent. In the silicon surface-alloy transistor, used in this investigation, spreading was found to occur on the heating portion of the alloying cycle and to be strongly dependent on orientation for (111) oriented material. Use of (100) and (110) oriented silicon essentially eliminates spreading, but results in shorted transistors. On lapped surfaces and thick silicon oxide films, the identity and the retractive action of the crystal plane is lost. Thermal gradients in the silicon produce a directional movement toward the hot zone that is also strongly dependent on orientation.

These spreading problems are alleviated through an extremely rapid rate of heating: on the order of 9,000 to 18,000°C/min. The dissolution of silicon is accomplished by an unsaturated solution at the final alloying temperature and spreading is essentially eliminated. Rapid heating, coupled with silicon having a low density of edge dislocations and close control of pre-alloying base-width, evaporated aluminum film thickness, final alloying temperature, and cooling cycle results in junctions that are planar-parallel with a significant improvement in the distribution of electrical characteristics.

[Tear sheets of this article are available on written request]

Alloying Cycle

One of the approaches to solving the spreading problem is an alteration of the alloying cycle. It was established early in the investigation that spreading occurred during the heating portion of the alloying

cycle. For instance, heating at a rate of approximately 450°C/min. to 900°C with a quick quench of <20 seconds to room temperature did not produce a noticeable reduction in spreading when compared to a slow cooling rate of <50°C/min. A slower rate of heating than 450°C/min. greatly aggravated the spreading problem. Extending the time at the equilibrium alloying temperature had a negligible effect on spreading.

A relative comparison of spreading over the range of alloying boat temperatures of 600°C to 890°C indicates that spreading increases rapidly with a higher final alloying temperature. The photomicrographs in

*This investigation was supported in part by a U. S. Signal Corps Contract, No. DA-36-039-SC-72686. Presented at the Electron Device Conference, Washington, D. C., Oct. 1958.

†Lansdale Tube Co., Division, Philco Corp., Lansdale, Pa.

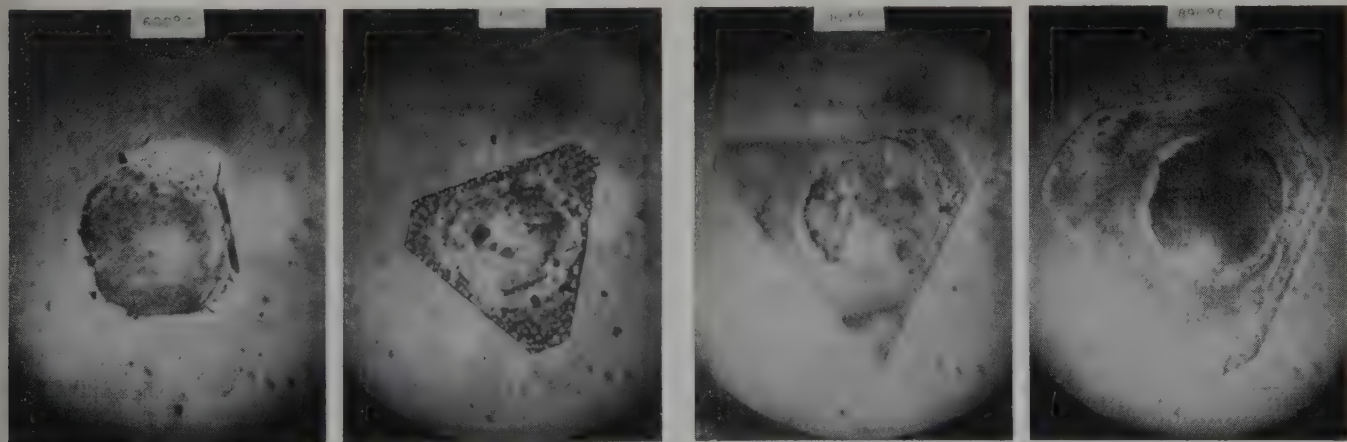


Fig. 13—Effect of temperature on spreading. Magnification $\approx 100X$.

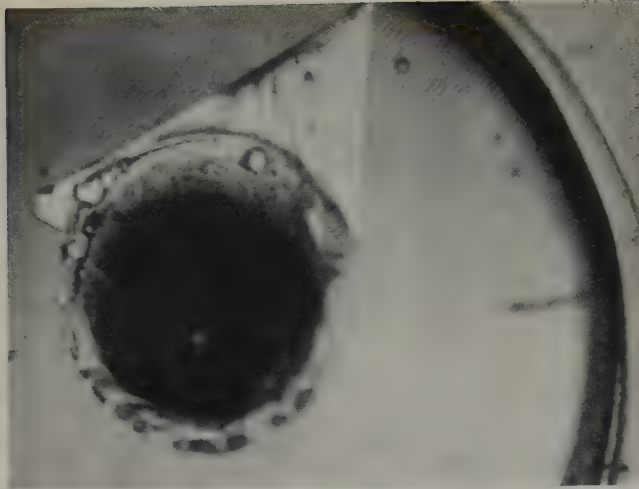


Fig. 14—Effect of thermal gradient on directional movement of molten zone. Magnification $\approx 150\times$.

Fig. 13 illustrate this spreading for four end temperatures from 600°C to 890°C . The equilibrium alloying time at each temperature was five minutes with a heating rate of approximately $450^{\circ}\text{C}/\text{min}$. and a cooling rate of approximately $200^{\circ}\text{C}/\text{min}$. These samples were chosen to indicate the extremes in spreading that may be observed for a given alloying temperature. The rate of movement of the sides of the triangle is approximately 4 times less than that of the apexes. The maximum surface movement from the initial circular geometry for each of the four temperatures is tabulated below. At 890°C the electrode area has more than doubled.

Temperature ($^{\circ}\text{C}$)	Maximum Movement (mils)
890	4.9
825	4.2
750	2.1
600	1.0

The above data indicates that, from the spreading aspect, a lower alloying terminal temperature produces less spreading. However, the aluminum solubility in solid silicon is retrograde,^{[9], [10]} and for increased conductivity of the recrystallized region and higher injection efficiency, the highest possible alloying temperature consistent with fabrication techniques is desirable. Conductivity of the recrystallized region, from four point probe resistivity measurements (tabulated below), indicates a five-fold improvement for 900°C over 600°C as the end alloying temperature.

Alloying Temperature ($^{\circ}\text{C}$)	Conductivity ($\text{ohm}^{-1}\text{—cm}^{-1}$)
600	11
700	15
800	20
900	50

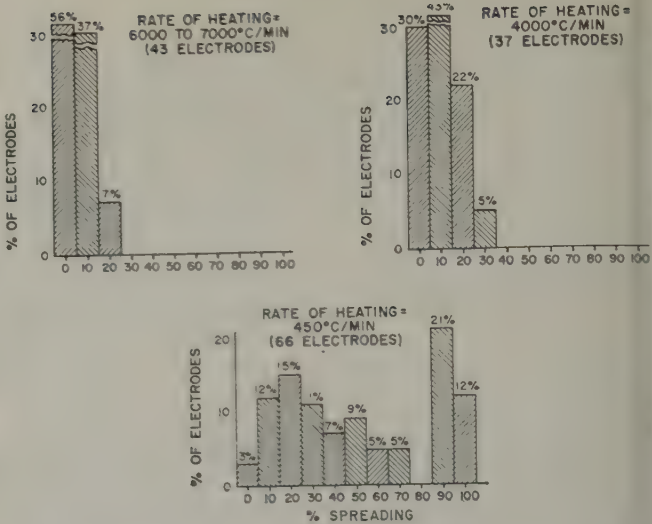


Fig. 15—Effect of heating rate on the distribution of spreading.

Another factor observed to affect electrode configuration is the temperature gradient across the silicon blank. Fig. 14 is a photomicrograph illustrating the directional movement of the molten zone in one minute after a thermal gradient in excess of $500^{\circ}\text{C}/\text{cm}$ with a mean zone temperature of approximately 900°C had been established. The directional movement is toward the hot zone and is strongly dependent on orientation. The rate determining factor for this movement appears to be a solution-diffusion-recrystallization phenomenon similar to that reported by Wernick.^{[11], [12]} Thus, one of the factors to be controlled during alloying is the thermal gradient.

From these experiments, and those of Mueller^[1], Pankove^[2], Goldstein^[3], and Wernick^{[11], [12]}, it is seen that the solution to the spreading problem lies in the control of the solution rate on the rising portion of the alloying cycle and the elimination of thermal gradients across the blank. The slower the dissolution rate, the greater the differentiation between atomic planes having different solution rates. However, with an extremely rapid solution rate, the crystal forces are no longer predominant and dissolution proceeds more uniformly in all directions. Thus, by rapid heating to the equilibrium alloying temperature, alloying takes place rapidly and uniformly in all directions at the high equilibrium temperature. This process continues until the solution becomes nearly saturated, after which the leveling action of the (111) plane occurs to produce planar-parallel junctions.

In order to obtain the rapid heating that is effective in limiting spreading, conventional radiant alloying furnaces and graphite alloying boats with a large mass are not satisfactory because of the thermal inertia of the boat. In practice, rf heating with a thermal load as small as possible is used to obtain an extremely rapid temperature rise.

Where heating rates of $1500^{\circ}\text{C}/\text{min}$. produce satis-

factory results in germanium transistors^[1], heating rates of 6000 to 9000°C/min. over the temperature range of 550°C to 900°C were found to be necessary to produce a substantial reduction in spreading, rates of the order of 18,000°C/min. are required.

In Fig. 15 the effect of changing the heating rate from 450°C/min. to >6000°C/min. on the distribution in spreading area is indicated. As shown in the graphs, the spreading was reduced from an average increase in area of 52% at a heating rate of 450°C/min. to 5% at 6000 to 9000°C/min.

With extremely rapid heating and close control of (1) pre-alloying base-width, (2) evaporated aluminum thickness, and (3) equilibrium alloying temperature, silicon surface alloy transistors are being fabricated from low dislocation density silicon with very little spreading and considerable improvement in electrical characteristics. This improvement is illustrated in Fig. 16 where distribution plots of current gain (h_{fb}), input impedance (h_{ib}), and output capacitance (C_{ob}), of transistors fabricated with a heating rate of >6000°C/min. are compared with transistors heated at a rate of 450°C/min. The most significant improvement lies in closer control of the distribution of parameters. The above distributions were obtained from a statistical sampling of over 3500 transistors. Alloying was performed in a dry hydrogen atmosphere with one minute at the equilibrium temperature of 900°C and a cooling rate of 200°C/min. to 600°C. The junctions formed were planar-parallel and similar to that of Fig. 5. With further increases in heating rates (on the order of 18,000°C/min or more), an additional reduction in spreading is expected with a corresponding improvement in the distribution of electrical characteristics.

Acknowledgements

The authors wish to extend their thanks to M. Sellani and R. Chu for their assistance in performing some of the experiments, and to W. MacGeorge for the preparation of the pilot run samples with rapid heating.

Errata—We regret that the magnification data given in connection with Figs. 8, 11, and 12 in Part 1 of this article were erroneous. The following corrections are to be noted. In Fig. 8 the magnification is $\approx 175X$; in Fig. 11, it is $\approx 150X$; in the left hand illustration of Fig. 12, it is $\approx 1.5X$ while in the right hand illustration of this figure it is $\approx 55X$.

References

- [1] C. W. Mueller, "Alloying Properties of Germanium Free of Edge Dislocations", *RCA Review*, Vol. XVIII, June 1957.
- [2] J. I. Pankove, "Effect of Edge Dislocations on the Alloying of Indium to Germanium", *Journal of Applied Physics*, Vol. 28, No. 9, Sept. 1957.
- [3] B. Goldstein, "The Dissolution of Germanium by Molten Indium", *RCA Review*, Vol. XVIII, June 1957.
- [4] N. P. Burchan, L. E. Muller, T. R. Rabillard, N. C. Vanduwal, and R. W. Westburg, "Germanium Alloy Junction Transistors", *Transistor Technology*, Vol. 3, D. Van Nostrand Co., Inc., p. 175.
- [5] I. M. Goldey, "Evaporation and Alloying to Silicon", *Transistor Technology*, Vol. 3, D. Van Nostrand Co., Inc., p. 231.
- [6] A. D. Kurtz, S. A. Kulin, and B. L. Averbach, "Effect of Dislocations on the Minority Carrier Lifetime in Semiconductors", *Phys. Rev.*, Vol. 101, 1285, (1956).
- [7] A. C. Chynoweth and G. L. Pearson, "Effect of Dislocations on Breakdown in Silicon P-N Junctions", *J. Appl. Phys.* 29, 1103 (1958).
- [8] Personal Communication on germanium transistors from E. S. Schlegel of Lansdale Tube Company Laboratories.
- [9] R. C. Miller and A. Savage, *J. Appl. Phys.*, 27, 1430 (1956).
- [10] D. Navon and V. Chernyshov, "Retrograde Solubility of Aluminum in Silicon", *J. Appl. Phys.*, Vol. 28, 823 (1957).
- [11] J. H. Wernick, "Determination of Diffusivities in Liquid Metals by Means of Temp. Gradient Zone Melting", *J. Chem. Phys.* 25, 47 (1956).
- [12] J. H. Wernick, "Effects of Crystal Orientation, Temperature and Molten Zone Thickness in Temperature-Gradient Zone-Melting", presented at the AIME Semiconductor Symposium, New York, Feb. 1956.

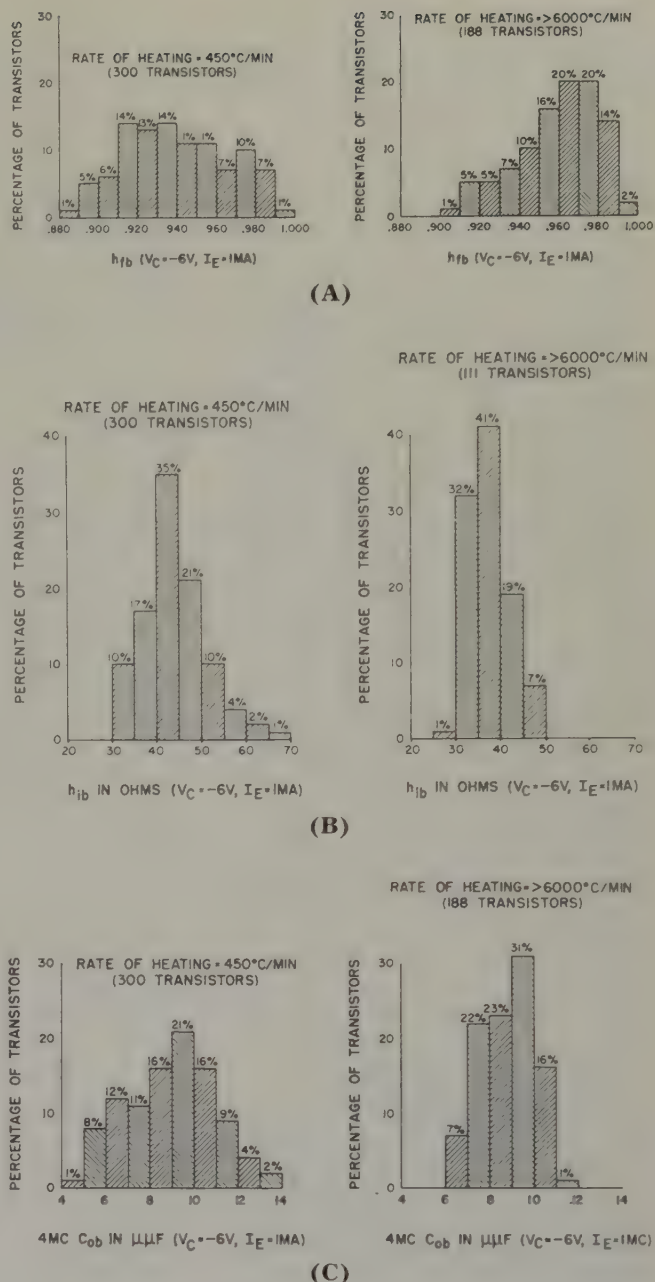


Fig. 16—Comparison of rapid and slow heating rates on the distribution of current gain (A), input impedance (B), and output capacitance (C).

BOOK REVIEWS . . .

TITLE: The Solid State for Engineers

AUTHOR: Maurice J. Sinnott

PUBLISHER: John Wiley & Son Inc. 1958

The Solid State for Engineers introduces the engineer to the principles underlining the behavior of solid state materials.

The first chapter introduces the subject in terms of the structure of matter starting with basic nuclear physics. Various properties of the elements are listed together with certain basic relationships between mass and energy.

Chapter II entitled "Crystallography" presents matter in the crystalline state. The fourteen theoretical space lattices of Bravais are illustrated and defined in terms of seven crystal system or sets of axes. The crystal is carefully explored and several examples are worked out to illustrate problem technique. Crystalline properties and methods of determination follow in the next chapter, which is devoted to X-Ray and Electron Diffraction.

Chapters IV and V discuss equilibrium and rate processes. Thermodynamic concepts such as entropy and enthalpy are used to present the phase concept or relationship between variants, components and number of phases of a given system. These concepts are developed to explain the state of several variables. Rate processes or transformations are explained by both modern rate theory and the older Arrhenius and Boltzmann equations.

The remaining chapters of the book deal with solids in general. Covalent, metallic, ionic, and molecular solids are categorized in terms of properties, structures and binding forces. There are chapters on deformations and the theory of dislocations. Various electronic and magnetic properties such as the p - n junction effect, Zener breakdown, magnetostriction and rectification are discussed in chapters XVII and XVIII. The book concludes with chapters on optical properties and miscellaneous surface phenomena.

The Solid State for Engineers is a unique collection of the principles and data concerning the behavior of material in the solid state, of particular interest to the engineer. The presentation is excellent making the book a valuable adjunct to the library of the transistor engineer.

TITLE: Logical Design of Electrical Circuits

AUTHORS: Rene A. Higonnet and Rene A. Grea

PUBLISHER: McGraw Hill 1958

Boolean algebra or the mathematics of logic was devised in the eighteen fifties and until recently was one of the more obscure sciences. *Logical Design of Electrical Circuits* is a book written to explain switching circuitry in terms of Boolean algebra.

The first chapter introduces the reader to the theory of sets or groups of classifications. Marbles are used to illustrate the generality of the treatment. The various logical operations of addition, subtraction and multiplication are clearly

defined and expressed in terms of the circles of Euler. Classification of combinations, permutations, symmetries and various operations for cases up to four variables are illustrated and listed.

Chapter II deals with two-terminal networks. The relay tree or fanning-out circuit is presented. Logical operations such as the sum and product are explained as relay circuit paths. Various complementary circuits and algebraic simplification methods are detailed together with methods of simplification by inspection.

Chapters III and IV deal with geometrical representations of combinations and simplification of circuits. Two relay combinations are represented by a plane, the case of three relays or three variables by a cube. Circuit simplification by elimination of duplicate paths introduces the study of topological forms or configurations of the circuit.

The remaining chapters of the book treat a variety of topics. Sequential circuits are especially well treated in Chapter X. Chapter XI is a very clear presentation of the electrical characteristics of relays and methods of obtaining special circuit performance. Chapter XII deals with rectifiers and vacuum tubes as switching elements. There is a complete table of circuits for various tube configurations together with their equivalent contact circuits. The appendix contains an extensive table of four relay contact networks.

Logical Design of Electrical Circuits is an intensive study of switching circuits analyzed in a systematic manner. Many examples, tables, and illustrations are used to clarify the text, making this book a well presented, understandable treatment of a complex topic.

TITLE: Solid State Magnetic and Dielectric Devices

AUTHOR: Harold W. Katz, Editor

PUBLISHER: John Wiley & Sons

Solid State Magnetic and Dielectric Devices is a rigorous, thorough treatment of ferrite and titanate devices, a topic of vast importance in the field of semiconductors.

The opening chapters develop a theory of solid state in terms of the interaction of electric and magnetic fields in matter. Chapter I introduces electrostatic and magnetostatic field theory starting with Coulomb's law and the H and B field theory. Chapter IV reviews some of the more basic concepts of solid state physics. Paramagnetism, and diamagnetism are explained as ordered and disordered arrays of atomic spins.

The next chapters deal with electrostrictive and magnetostrictive systems. Chapter IV discusses non-linear magnetic and dielectric materials with respect to computer or switching applications.

Perhaps the most useful chapter in the book is Chapter V which deals with electromechanical applications of piezoelectric materials. Here the ceramic transducer and filler are discussed. A fund of design information on methods, modes of vibration, control of spurious response and geometry is presented.

The balance of the book covers a wide range of topics. Magnetic and dielectric amplifiers (Chapter VIII), square-law materials and digital techniques (Chapter IX), measurements (Chapter XI) and a fascinating discussion of magnetic recording (Chapter X) round out the work.

Solid State Magnetic and Dielectric Devices is a fundamental, lucid presentation of the topic. The book is a collection of the work of many eminent authors. It is well written and should serve as an adjacent text to the study of semiconductors.

TITLE: Symposium on Cleaning of Electronic Device Components and Materials

PUBLISHER: American Society for Testing Materials (Publication #246)

The Symposium on Cleaning of Electronic Device Components and Materials is a collection of papers sponsored by the ASTM committee on Materials for Electron Tubes and Semiconductor Devices.

The nature of the modern miniature electron device has stressed certain aspects of component contamination and handling not considered as thoroughly in earlier practice. The papers presented here deal with methods of miniaturization, measurement and evaluations of material contamination and processes of handling and working of pure materials.

There are several interesting papers on laboratory planning and dust control as well as methods of eliminating physical contaminants. A paper by Johnson is an interesting description of "Operation Snow White" a high reliability tube assembly operation. There are many papers on laboratory measurement techniques utilizing new concepts. Of particular interest is the paper by Slater and Donahue on Radiotracers to evaluate parts cleaning. Chemical processes are also reviewed with stress placed on water purity and conductivity measurements. Cause and effect cleaning methods to improve vacuum tube reliability are discussed by Hickie and Crawford. There are several interesting papers on the use of the mass spectrometers for gas studies and process evaluation.

The papers presented in this symposium collection are extremely interesting, well prepared and of obvious value to laboratory scientists and quality control engineers. The discussions printed after each paper adds much clarity to the presentations.

TITLE: Germanium, Supplement, System No. 45 of the 8th Edition of Gmelins Handbook of Inorganic Chemistry, 1958, XLIV. (576 pgs., 290 graphs)

PUBLISHER: Verlag Chemie, GmbH., Weinheim/Bergstr. (West Germany). (Available in the USA through any American book importer).

The present Germanium Supplement volume for the first time features bilingual English and German tables of contents. The Supplement to the 1931 Germanium volume encompasses the results of all research published between 1931 and 1953. The 576 pages of the Sup-

plement contrast with the 62 pages of the 1931 volume. As a transition element with both metallic and non-metallic properties, germanium tends to form homopolar compounds like GeH_4 . As a homolog of carbon, it has the ability similar to silicon to form organic compounds with Ge-C bonds, having partly chain and ring-form structure. The more than 200 compounds of this type which are now known have been tabulated in the new volume, moreover, several properties and methods of preparation are quoted.

The electrical properties of germanium are divided into several main sections (totaling 255 pages). The first section treats the conductivity phenomena of pure, intrinsic material. In the second section, the electrical properties associated with impurity conduction in germanium are treated; extensive detail on the various methods for production of donors and acceptors in germanium are also included. The third section is devoted to the physics of germanium rectifying junctions and discusses the numerous phenomena of diodes and transistors.

A final section consists of a comprehensive review of the application of germanium diodes and transistors, and presents some technical circuitry data.

In connection with the electrical properties, the photoelectric phenomena are exhaustively described (68 pages), including also the practical significance already acquired by photodiodes and phototransistors, as well as germanium photocells.

The presentation of the physics of germanium may be characterized as one of the most complete monographs on the subject, containing the most recent research results.

TITLE: Electronic Circuit Theory

AUTHORS: H. J. Zimmerman, S. J. Mason

PUBLISHER: John Wiley & Sons 1959

Electronic Circuit Theory is a book dealing with the analytical concept of analysis of electronic circuits, in terms of a model or "idealized abstraction" approach.

The first four chapters develop the concept of diode action as a non-linear circuit phenomena as opposed to linear R, L, and C elements. The idealized diode is considered as both a semiconductor junction and in terms of thermionic and cold cathode emission. Resistive diode circuits are next treated as model circuits utilizing a graphical piecewise-linear approach. This method leads to a thorough consideration of rectification and detection. Many circuits are covered, varying from the simple diode AM detector to the balanced modulator and demodulator.

Chapter V entitled "Transistor Model and Circuits" is a logical outgrowth of the previous diode presentations. A fairly uncommon but highly understandable treatment of the transistor as an emitter-to-base collector-to-base dual diode leads to a very clear concept of transistor action. The piecewise-linear curve presentation is especially helpful here in the analysis of transfer curve characteristics. The equations for impedance and gain in all three configurations are developed and the high frequency equivalent circuits are presented.

The next chapters build the vacuum triode and other control valves in a similar manner of piecewise-linear analysis. A particularly useful treatment of the

topic of wave shaping and amplification may be found in chapter VIII in addition to a well written presentation of methods of wave form generation, in the following chapter. The remaining two chapters deal with oscillations in RLC circuits, symmetry, and balanced circuits.

Electronic Circuit Theory is quite useful as a source of basic analytical techniques. This book indicates a method of analysis, while relatively simple, is intuitively elegant, providing a clear understanding of basic circuit phenomena. The book is exceptionally well written, clear and highly readable recommending it as a very useful engineering adjunct.

TITLE: Transistor Workshop Lecture Series

PUBLISHER: IRE—(Boston Section) 1959

This book is a compilation of a series of six lectures presented by the Boston section of the IRE. The lectures comprise a basic course in transistor theory and applications.

The first paper by Rice builds the foundation of the transistor as an amplifying and control device. The various configurations are presented and the transistor is considered as a circuit element in terms of its diode action, with the explanations based upon the devices' characteristic curves. Circuit applications are discussed and several descriptive schematic diagrams are presented to illustrate typical configurations.

The second paper outlines some of the characteristics of the many available transistors and how to select the proper transistor for an application from the parameters of interest. The various terms in use are discussed. Storage time, fall time, delay time and rise time are clearly defined. Static characteristics curves are reviewed and a set of test circuits are given to aid in the understanding of the terms. The switching time definitions are graphically illustrated.

The third lecture deals chiefly with transistor circuits used in commercial applications. Design considerations and special "short-cut" approaches are outlined. Special circuits for phonograph pickups are described together with some interesting observations.

Lectures four, five and six comprise the basic body of the book. Here the high frequency operation of transistors is discussed by Watson, together with an interesting comparison between amplifier types (Lecture 4). The applications of high power transistors are treated in Lecture five. Lecture six is an extremely valuable survey of operation of the transistor as a switch and covers a wide and useful range of topics from basic on-off considerations to actual flip-flop and counting circuitry. A set of data charts is bound into the volume providing a useful source of characteristic information to aid in the understanding of the material presented.

The *Transistor Workshop Lecture Series* is an excellent introduction to the transistor and is to be highly recommended to the student as well as the design engineer, not yet familiar with transistors.

TITLE: Proceedings of the National Electronics Conference Volume XIV

PUBLISHER: National Electronics Conference Inc., Chicago 1, Illinois 1959.

Volume XIV of the National Electronics Conference is the latest collection of the

papers presented at the NEC sessions. The conference itself is sponsored by several engineering societies in conjunction with various colleges and universities throughout the United States. The papers collected in this volume represent the work of many university sponsored research programs in addition to development programs in industry and professional group presentations.

The book is divided into twenty-five topics dealing with the general field of electronics. There are two chapters on transistors in which papers dealing with transistor circuitry, parameters and applications are presented. Additional transistor applications may be found throughout the other sections. Sections on Solid State and Filter Design contain interesting semiconductor applications. The paper on V.H.F. power switching with Semiconductor Diode (page 325) is typical. A high speed transistorized Digital-To-Analog Decoder is discussed in the Computer section.

There are sections on Radar and Radio Navigation. Doppler Radar systems are discussed in some detail. Network Theory, Television, Servomechanisms and Noise are topics also covered by excellent papers. Engineering Management and Engineering Writing and Speech are typical of several non-technical topics treated.

The Proceedings of the National Electronics Conference, Volume XIV is a collection of the results of the latest thinking in many topics in the electronics field. This book deserves a place as a reference work and a source of the latest information in the library of the design engineer.

Stephen E. Lipsky

Engineer Technical Sales

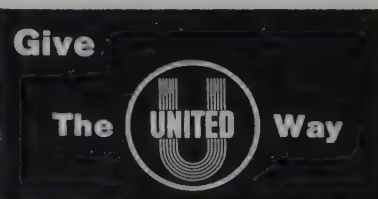
Experienced Industrial Sales to Electronic Component Manufacturers. Application of newly developed EPOXY formulations for packaging semiconductors and miniature electronic components.

Background in mass production of electronic components desirable. Excellent growth opportunity. Salary open.

EPOXY PRODUCTS, INC.

A Division of Joseph Waldman & Sons
137 Coit Street

Irvington, New Jersey
ESsex 5-6000



SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Transistors for Electronic Switching	Bell Labs Rec March 1959	Discussion of the applications of switching transistors in telephone circuits.	T. R. Robillard R. W. Westberg
Use of Active Material in Three-Level Solid State Maser	Bell Syst Tech J1 March 1959	Maser action is based on favorable relaxation time ratio in signal and idler transitions. Relaxation time is affected by doping.	E. O. Schulz-DuBois H. E. D. Scovil R. W. DeGrasse
The Three-Level Solid State Traveling Wave Maser	Bell Syst Tech J1 March 1959	Broadband very-low noise microwave amplification can be obtained from solid state maser action in a propagating microwave structure.	R. W. DeGrasse E. O. Schulz-DuBois H. E. D. Scovil
A Miniaturized Negative-Impedance Voice Repeater Employing Transistors	Comm and Electronics (AIEE) March 1959	Series and series-shunt type repeaters provide transmission gain when inserted in a 2-wire telephone line.	A. S. Howell
How Diodes Generate Functions	Control Engrg March 1959	Description of basic diode-resistor voltage-sensitive network leading to a universal diode function generator	E. J. Galli
Inductance Bridge, Ring Modulator, Transistor Flip-Flop Form Static Switch	Electrical Des News March 1959	An adjustable inductance bridge, a phase-sensitive detector, and a transistor flip-flop are combined to form a static proximity limit switch.	
Series Transistors Expand Operating Range of D-C to D-C Converter	Electrical Des News March 1959	By operating transistors in series a d-c to d-c converter can be operated at higher supply voltages.	
Behavior of Semiconductor and Magnetic Materials in Radiation Environment	Electrical Mfg. March 1959	Theoretical and experimental behavior of several semiconductor and magnetic materials under radiation.	A. Boltax
A Temperature Control System for Transistors	Electronic App Vol 19 No 2 1958/1959	A simple system has been devised whereby the transistors are maintained at a temperature higher than the maximum likely ambient temperature.	H. Kemhadjian
Photoelectric Applications of Semiconductors	Electronic App Vol 19 No 2 1958/1959	A review article in which common properties of all photoelectric detectors are discussed, together with performance calculations.	F. Desvignes
Development and Final Design of Photomultiplier Tubes	Electronic App Vol 19 No 2 1958/1959	The specific problems involved in the technology of photomultipliers are reviewed.	G. Pietri
Transistor Amplifiers for D. C. Signals	Electronic App Vol 19 No 1 1958/1959	Basic types of direct-coupled and "chopper" type amplifiers are examined and compared.	M. Kemhadjian
Hall-Effect Generators	Electronic Design Mar 4 1959	How they work and how they are used.	W. E. Bulman
Standard Transistor Switching Circuits	Electronic Design March 18 1959	Circuits described were designed as compatible building blocks to be interconnected to perform complex functions.	T. A. Prugh
Designing a Transistor NOR Circuit for Minimum Power Dissipation	Electronic Design March 18 1959	The NOT function, AND function, and OR function performed by various combinations of NOR circuits.	E. L. Cox
Design of a Two-Transistor Binary Counter	Electronic Design March 18 1959	Three levels of design suggested, each level aimed for circuit operation under different conditions.	P. Emile Jr.
Keep Junction Temperatures Down	Electronic Design March 18 1959	Steps to be taken to achieve good performance. Graphs enable designer to determine efficiency of a fin.	W. Luft
How to Design for Transistor Reliability-I	Electronic Eq Eng March 1959	Basic reliability criteria for application of transistors are laid down.	J. B. Hangstefer L. H. Dixon Jr.
Design of a Transistor Electronic Switch	Electronic Eq Eng March 1959	Presentation of two simultaneous waveforms on an oscilloscope can be accomplished by a transistor switching instrument.	H. J. Wirth W. M. Oleson
Detectors for Infrared Radiation	Electronic Eq Eng March 1959	The sensitivity and responsibility of thermocouples and bolometers are covered with an introduction to photo detectors.	C. R. Betz
Increase the Input Impedance of Transistor Amplifiers	Electronic Ind March 1959	Description of a transistor amplifier with an input impedance of 8 megohms, a voltage gain of 40 db, and an output impedance of 600 ohms.	A. D. Evans
1959 Transistor Interchangeability Chart	Electronic Ind March 1959	Cross-referencing chart of transistors and their nearest equivalents.	
High-Power Transistor D. C. Converters	Elec Rad Eng (Br) March 1959	The transformer-coupled push-pull circuit is examined in some detail; circuit designs using silicon and germanium power transistors.	T. R. Pye *
Transistor Equivalent Circuit	Elec Rad Eng (Br) March 1959	Presentation of a new equivalent circuit for a transistor which is valid at all frequencies where the device gives useful gain.	D. A. Green
Improved R-C Oscillator	Electronics Mar 6 1959	Circuit description and components of the single frequency transistor oscillator designed to operate in the 4 cps to 350 kc range.	L. H. Dulberger
UHF Transistor Data	Electronics Mar 6 1959	Tabulation of commercially available transistors operating above 300 mc with characteristics.	H. Tulchin
Solid-State Thyratrons Available Today	Electronics Mar 6 1959	Tabulation of solid-state thyratrons with pertinent characteristics.	T. P. Sylvan
Transistors Improve Telemeter Transmitter	Electronics Mar 13 1959	Description of balloon-borne transistorized apparatus.	D. Enemark

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Encoder Measures Random Event Time Intervals	Electronics Mar 20 1959	A high-resolution random event encoder using semiconductors is described.	R. J. Kelso J. C. Groce
Digital Recorder Holds Data After Shock	Electronics Mar 20 1959	Description of recorder in which data are stored in ferrite cores that can retain the data even after a 6000-g shock.	C. P. Hedges
New Power Sources for Space-Age Electronics	Electronics Mar 20 1959	Collation of various devices and systems including tables.	D. Linden A. F. Daniel
Junction Silicon Diodes	Elec Exp 3/59 (Xpt) Elektrichestvo No 1 Jan 1959	A study is made of the technology of manufacture and the electrical properties of silicon rectifier diodes.	G. A. Zelikman Ia S. Levenberg I. P. Lukashova Iu. I. Sidorov S. V. Frank
On the Conditions Governing the Formation of Avalanche Processes in Point-Contact Transistor Relaxation Oscillators	Elec Exp 3/59 (Comp) Radiotekhi Elek No 1 Jan 1959	Relaxation oscillators based on point-contact transistors may be treated as devices containing a nonlinear voltage or current amplifier.	V. N. Iakovlev
The Effect of Interval Electric Fields in a Semiconductor on its Field Emission	Elec Exp 3/59 (Comp) Radiotekhi Elek No 1 Jan 1959	In order to explain observed experimental characteristics the effects produced by a strong field in a semiconductor must be included.	M. I. Elinson
A Generalized Resistor-Transistor Logic Circuit and Some Applications	IRE Trans Electronic Computers March 1959	Practical limitations such as using precision power supplies and components are discussed; practical circuits worked out.	S. C. Chao
Transistors for Cardiac Conduction System	IRE Trans Med Elec March 1959	Transistor amplifier attached to cardiac electrodes on the atrium and ventricle of a dog alleviates heart block.	E. Watkins, Jr.
Nitrogen in Silicon	J1 App Phys March 1959	The concentration of electrically active impurity states in silicon grown from melts containing around 10^{19} atoms per cm^3 of nitrogen is less than 10^{12} atoms per cm.	W. Kaiser C. D. Thurmond
Effect of Oxide Impurities on the Thermoelectric Powers and Electrical Resistivities of Bismuth, Antimony, Tellurium, and Bismuth-Tellurium Alloys	J1 App Phys March 1959	The thermoelectric powers of these materials depend in detail on the manner in which the thermal gradient is applied during measurement.	R. A. Horne
Sputtering Yield of Germanium in Rare Gases	JL App Phys March 1959	Sputtering yields of Ge bombarded by Ke^+ , Kr^+ , A^+ , Ne^+ , and He^+ ions under normal incidence at energies up to 400 ev have been determined.	N. Laegreid G. Wehner B. Meckel
Impurity Compensation and Magnetoresistance in p-type Silicon	J1 App Phys March 1959	A new method is proposed for determining the separate concentrations of acceptor and donor impurities in crystals of p-type silicon.	D. Long C. D. Motchenbacher J. Myers
High-Speed Switching Diodes from Plastically Deformed Germanium	J1 App Phys March 1959	Reduced minority storage effect permitted fabrication of diodes with turnoff times of the order of 10^{-9} sec.	G. L. Pearson R. P. Riesz
Recombination Centers on Ion-Bombarded and Vacuum Heat-Treated Germanium Surfaces	J1 App Phys March 1959	After annealing of the bombardment damage, a large number of acceptor type surface states approximately clamped the surface potential.	S. Wang G. Wallis
Associated Donor-Acceptor Luminescent Centers in Zinc Sulfide Phosphor	J1 Electrochem Soc March 1959	Zinc sulfide activated with copper or silver and co-activated with gallium or indium shows two emission bands.	E. F. Apple F. E. Williams
Effect of Various Etches on Recombination Centers at Germanium Surface	J1 Electrochem Soc March 1959	Density, energy levels, and capture probabilities of the recombination centers were measured before and after baking.	G. Wallis S. Wang
The Faraday Effect in Anisotropic Semiconductors	J1 Elec & Cont (Br) March 1959	The theory of the Faraday effect in semiconductors is extended to uniaxial crystals with spheroidal energy surfaces.	I. G. Austin
The Measurement of the Temperature Dependence of the Mobility and Effective Lifetime of Minority Carriers in the Base Region of Silicon Transistors	J1 Elec & Cont (Br) March 1959	This paper describes results of similar measurements on silicon transistors, giving however, temperature dependence of the effective lifetime of minority carriers in the base region.	D. M. Evans
Electrical Properties of Stannous Selenide	J1 Phys Soc Jap March 1959	The electrical resistivity, Hall coefficient, and thermoelectric power were investigated on pure and impurity-doped SnSe crystals.	S. Asanabe
A Method of Measuring the Resistivity and Hall Coefficient of Lamellae of Arbitrary Shape	Phillips Tech Rev March 1959	Hall effect measurements can also be made on arbitrarily shaped lamellae in which the stream-line pattern is not at all uniform.	L. J. van de Pauw
AC-DC Electroluminescence	Physical Review March 1 1959	The enhancement of electroluminescence by the superposition of a-c and d-c voltages has been observed in certain ZnS powder phosphors.	W. A. Thornton
Electroluminescence in Cuprous Oxide	Physical Review March 1 1959	Variations in light output studied as a function of frequency, wave shape, voltage, current, power, and changes in temperature.	R. Frerichs R. Handy
Anomalous Photovoltaic Effect in ZnS Single Crystals	Physical Review March 1 1959	Larger than band-gap photovoltages have been observed in crystals of ZnS with stacking faults.	A. Lempicki
Excitation Spectra and Temperature Dependence of the Luminescence in ZnS Single Crystals	Physical Review March 1 1959	The luminescence was measured for the region 80-500°K and for different wavelengths of existing light.	A. Halperin H. Arbell

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Infrared Absorption of Reduced Rutile TiO ₂ Single Crystals	Physical Review March 1 1959	Absorption of plane parallel plates having resistivities ranging from 3 to 0.01 ohm-m have been examined.	D. C. Cronmeyer
Photoconductor Performance, Space-Charge Currents, and the Steady-State Fermi Level	Physical Review March 1 1959	Analysis, via the concept of the steady-state Fermi level, indicates that the performance is limited by the injection space charge.	A. Rose M. A. Lampert
Effect of Pressure on the Infrared Absorption of Semiconductors	Physical Review Mar 15 1959	Measurements have been made on germanium, silicon, and tellurium in the pressure range of 1-2000 atmospheres.	L. J. Neuringer
Transistor Active Filters Using Twin-T Rejection Networks	Proc Inst EE (Br) Mar 1959 Part B	The introduction of a rejection type network into the feedback loop of an amplifier leads to bandpass characteristics similar to those of single tuned circuits.	A. E. Bachmann
Operating Experience with a Transistor Digital Computer	Proc Inst EE (Br) Mar 1959 Part B	This paper describes the performance, and the failure rate of point-contact transistors.	R. C. M. Barnes J. H. Stephen
A New High-Speed Digital Technique for Computer Use	Proc Inst EE (Br) Mar 1959 Part B	A new method is described for realizing logical functions using square-loop ferrite cores and transistors.	D. A. Eldridge
A Method for Testing and Establishing the Rating of Semi-Conductor Rectifiers Under Dynamic Conditions	Proc Inst EE (Br) March 1959 Part C	Principle of operation of the cheater circuit, synchronous switching, and apparatus utilizing commutator switching.	J. I. Missen
The Physical Principles of a Negative-Mass Amplifier	Proc IRE March 1959	This paper describes the physical principles of a new class of solid-state devices used from low frequencies up to very high frequencies in the microwave region.	H. Kromer
The Band Between Microwave and Infrared Regions	Proc IRE March 1959	Generation, detection, control, transmission, measurement factors, problems, and devices discussed.	I. Kaufman
Simple General Analysis of Amplifier Devices with Emitter, Control and Collector Functions	Proc IRE March 1959	Comparative signal amplifying capabilities of lumped solid-state and vacuum tube devices are described in terms of charge control, charge storage, and charge motion.	E. O. Johnson A. Rose
Nonlinear-Capacitance Amplifiers	RCA Review March 1959	A review article providing an explanation of the operations of variable-capacitance amplifiers in simple physical terms.	L. S. Nergaard
Gain-Bandwidth Product for Photoconductors	RCA Review March 1959	Departures from ideal performance analyzed; performance in several well known devices discussed.	A. Rose M. A. Lampert
Properties of Deep Traps Derived from Space-Charge-Current Flow and Photoconductive Decay	RCA Review March 1959	The current-voltage characteristics of a single crystal of CdS have been measured, from which data performance is evaluated.	R. W. Smith
Gains, Response Times and Trap Distributions in Powder Photoconductors	RCA Review March 1959	Trap distributions have been derived from photocurrent decay curves. These show a nearly exponential decrease of trap density with increasing trap depth.	H. B. DeVore
Magnetics for Computers-A survey of the State of the Art	RCA Review March 1959	The present-day applications of magnetics and semiconductor devices to random-access memories and logic switching are surveyed and appraised.	J. A. Rajchman
Unified Representation of Junction Transistor Transient Response	RCA Review March 1959	Result applies to any circuit configuration of the transistor. Specific results usually stated in separate expressions can be derived from a general equation.	A. Harel J. F. Cashen
The Megacoder, A High-Speed Large-Capacity Microminiature Decoder for Selective Communication	RCA Review March 1959	Transistorized device can be preset to respond to any one of one million possible code combinations provided by a bipolar 20-pulse binary code.	H. Kihn W. E. Barnette
Large Scale Preparation of Ultra-Pure Silicon	Res Appd in Ind (Br) Mar 1959	Requirements, difficulties in preparing pure silicon, methods for preparing pure silicon—various processes.	J. M. Wilson
The Application of Dynistor Diode to "Off-On" Controllers	Semiconductor Prod March 1959	Semiconductor device for use in small control circuits, and which provides high output power.	P. F. Pittman
Transistor AC and DC Amplifiers with High Input Impedance	Semiconductor Prod March 1959	A class of transistor amplifiers is described in which high input impedance is achieved with low-input-impedance circuit bias stability.	R. D. Middlebrook C. A. Mead
Transistorized Entertainment type FM Receivers	Semiconductor Prod March 1959	Design considerations of the various stages of a transistorized FM receiver.	H. Cooke
Dislocations In Crystals	Semiconductor Prod March 1959	Many important properties of crystals are determined by the imperfections present within.	J. R. Patel
Research in Preparation of Hyperpure Single Crystal Silicon Carbide	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 545	The design and operation of a high temperature (2600°C) graphite tube furnace is given.	
Semiconductor Device Set Mx-2009 (XW-1) GP	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 288	Development of a high voltage 3-phase bridge silicon power rectifier assembly.	
30 MC Silicon Amplifier (Device 22)	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 555	Fabrication processes are detailed.	M. Dukat G. Freedman
Investigation and Evaluation of an Electronic Gate	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 438	A crystal diode gate suitable for sampling accurately small changes in resistance 0.1% at the level of 10 ⁶ ohms, is investigated.	O. P. Manley
Evaluation of NOLC 15-Channel Transistorized Electronic Commutator	U. S. Govt Res Rep Mar 13 1959 Order LC PB 135 339	An evaluation is made of a 15-channel transistorized multiplexer for use in a new PAM-FM telemeter or as a commutator.	T. B. Jackson



NEW SPECIAL DIODES

(Continued from August 1959)

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EF- FICIENT %/°C	MFR. { See code at start of chart }
	MIN.	MAX.	@ I _z	Z @ I _z				
	E _{b1} (volts)	E _{b2} (volts)	 (ma)	 (ohms)	 (ma)			
1M6.8Z Δ	5.4	8.2	37	3.5	37	1000	.04	MOT
1.5M6.8Z Δ	5.4	8.2	55	2.7	55	1500	.04	MOT
10M6.8Z Δ	5.4	8.2	370	1.2	370	10W	.04	MOT
50M6.8Z Δ	5.4	8.2	1850	.40	1850	50W	.04	MOT
1M7.5Z Δ	6.0	9.0	34	4.0	34	1000	.045	MOT
1.5M7.5Z Δ	6.0	9.0	50	3.0	50	1500	.045	MOT
10M7.5Z Δ	6.0	9.0	335	1.3	335	10W	.045	MOT
50M7.5Z Δ	6.0	9.0	1700	.50	1700	50W	.045	MOT
1M8.2Z Δ	6.6	9.8	31	4.5	31	1000	.048	MOT
1.5M8.2Z Δ	6.6	9.8	46	3.5	46	1500	.048	MOT
10M8.2Z Δ	6.6	9.8	305	1.5	305	10W	.048	MOT
50M8.2Z Δ	6.6	9.8	1500	.60	1500	50W	.048	MOT
1M9.1Z Δ	7.3	10.9	28	5.0	28	1000	.051	MOT
1.5M9.1Z Δ	7.3	10.9	41	4.0	41	1500	.051	MOT
10M9.1Z Δ	7.3	10.9	275	2.0	275	10W	.051	MOT
50M9.1Z Δ	7.3	10.9	1370	.70	1370	50W	.051	MOT

Under Type No.

□ - Double Anode Type

* - Developmental Type

Δ - Also available with ± 5 percent tolerance

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I _f @ E _f (mA) (volts)		Reverse Impedance @ 25°C		Recovery Characteristics				MFR. { See code at start of charts }	
						Z (K ohms)	VOLTAGE RANGE	TEST CONDITIONS	Z _{rec.} @ time (t) (K ohms) (usec)				
				E _{b1} to E _{b2} (volts)	Fwd. Rev. I _f to E _b (ma) (volts)								
1N643A	S1		200	100	1.0	1.0	100	5.0	40	200	.30	HUG	
1N662A	S1		100	100	1.0	.20	50	5.0	40	100	.50	HUG	
1N663A	S1		100	100	1.0	.10	75	5.0	40	200	.30	HUG	
1N818	S1		70	30	1.5		60	20	90	80	.50	CTP	
1N837	S1		100	150	1.0	.10	75	30	35	400	.50	HUG	
1N837A	S1		100	150	1.0	.10	80	30	35	400	.30	HUG	
1N838	S1		150	150	1.0	.10	125	30	35	400	.50	HUG	
1N839	S1		200	150	1.0	.10	175	30	35	400	.50	HUG	
1N840	S1		50	150	1.0	.10	40	30	35	400	.30	HUG	
1N841	S1		150	150	1.0	.10	120	30	35	400	.30	HUG	
1N842	S1		200	150	1.0	.10	160	30	35	400	.30	HUG	
1N843	S1		250	150	1.0	.10	200	30	35	400	.30	HUG	
1N844	S1		100	200	1.0	.10	80	30	35	400	.50	HUG	
1N845	S1		200	200	1.0	.10	160	30	35	400	.50	HUG	
MA4223	S1	30	30	10	1.1			10	5.0	Complete-8m		MIC	
OA41	Ge	90	60	5.0	1.0	400min.	20	50	30	35	50	.50	TKD
SFD109	Ge		90	10	1.5	400	20	50	30	35	50	.50	CSF

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
1N269E	1	At 3060Mc.-conv. loss-5.5db max. NR-1.5 times max. At 9375Mc.-conv. loss-6.0db max. NR-1.4 times max.	QAH
1N830	2	UHF Detector, Micro-Min diode	SYL
1N831	1,2	S-Band Mixer, Micro-Min diode	SYL
1N832	1,2	X-Band Mixer, Micro-Min diode	SYL
1N833	1,2	X-Band Detector, Micro-Min diode	SYL
1N836		Parametric Amplifier Diode, Glass Package	HUG
1N2386		Parametric Amplifier Diode, Microwave Package	HUG
1T51		Thermal Compensation Diode; PIV-25V., Thermal Coeff.--.002V/°C Avg. I-100ma	SONY
1T52		Thermal Compensation Diode; PIV-25V., Thermal Coeff.--.002V/°C Avg. I-25ma	SONY
KF11	4	Grain boundary photo diode	TKD
OA21	2,6	UHF - Mixer diode	TKD
PHGI	4	30V,max.,Min. sens.-70ma/lumen; dark I-10ua at 30V	CSF

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes

4. Photodiodes
5. Solar Cells

6. Harmonic Generator diodes
7. 4-Layer bistable diodes

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Aug. 14, 1956 to Sept. 18, 1956. In subsequent issues, patents issued from Sept. 18, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

August 14, 1956

2,759,133 Semiconductor Devices—C. W. Mueller. Assignee: Radio Corporation of America. A semiconductor device comprising a body of semiconductive material having therein zones of different conductivity types separated by a rectifying barrier, and a heat radiating member in intimate thermal contact with said barrier.

2,759,142 Transistor and Electromagnetic Control Apparatus—B. H. Hamilton. Assignee: Bell Telephone Laboratories. In combination: a saturable reactor, a d-c source, two transistors, and means for impressing upon the base of one transistor, with respect to a terminal of said source, a potential which may vary for controlling the currents flowing through the control windings of said reactor.

August 21, 1956

2,760,004 Number Group Circuit—W. A. Reenstra. Assignee: Bell Telephone Laboratories. A telephone switching system comprising lines and trunks and a transistor switching network for establishing talking connections between lines and trunks.

2,760,007 Two Stage Transistor Feedback Amplifier—J. C. Lozier. Assignee: Bell Telephone Laboratories. A device including a series negative feedback path between the emitter of a second transistor and the base of a first transistor, and a shunt negative feedback path between the collector of said second transistor and the emitter of said first transistor.

2,760,012 Semiconductor Velocity Modulation Amplifier—R. W. Peter. Assignee: Radio Corporation of America. An arrangement including a wave guide filled completely by a semiconductor, said semiconductor being insulated from the walls of the waveguide and being used for guiding an electromagnetic wave along a path within the semiconductor with a phase velocity less than the corresponding wave velocity in free space.

2,760,013 Semiconductor Velocity Modulation Amplifier—R. W. Peter. Assignee: Radio Corporation of America. A device including a waveguide with phase retardable means comprising a series of planar plates within said waveguide and normal to the direction of flow in a path within a semiconductor.

2,760,060 Ultrahigh Frequency Converter System Having a Crystal Diode Mixer—C. W. Wittenburg, C. C. Hermeling. Assignee: Radio Corporation of America. A device comprising a crystal diode, mixer, a resonant signal input circuit, means for providing a series-resonant signal output path, an oscillation generator tunable within the uhf band, and an intermediate amplifier stage.

2,760,070 Amplitude Stabilized Transistor Oscillator Circuit—E. Keonjian. Assignee: General Electric Company. A transistor oscillator circuit which maintains the amplitude of oscillation at a constant value over a variable frequency range, and which eliminates the need for an auxiliary source of reference potential.

2,760,087 Transistor Memory Circuits—J. H. Felkes. Assignee: Bell Telephone Laboratories. A circuit for the storage of a binary bit of information in the form of either a One or a Zero utilizing a transistor flip-flop circuit.

2,760,088 Pulse Shaping Circuits—G. F. Pittman Jr., R. O. Decker, R. L. Bright. Assignee: Westinghouse Electric Corporation. A pulse shaping circuit for supplying pulses of constant volt-second area to a load in response to input pulses utilizing two transistors and a magnetic core element.

August 28, 1956

2,761,020 Frequency Selective Semiconductor Circuit Elements—W. Shockley. Assignee: Bell Telephone Laboratories. A signal transmitting device comprising an elongated body of semiconductive material, the resistance per unit length of which varies cyclically through a plurality of cycles between the ends of said body.

2,761,095 Selenium Rectifier—S. S. Fry. Assignee: Fansteel Metallurgical Corporation. A selenium rectifier, the blocking layer of which is composed of an organic borate compound having the general formula $(RO)_3B$ Where R is a radical selected from the class consisting of alkyl, aryl, and alkaryl radicals.

September 4, 1956

2,761,909 Multifrequency Oscillator—R. L. Wallace Jr. Assignee: Bell Telephone Laboratories. A two-frequency oscillator which comprises a symmetrical transistor, two feedback paths including two frequency determining circuits, and means for rendering said transistor alternately operative in opposite directions,

and means for simultaneously disabling said feedbacks in alternation.

2,761,916 Self-Biasing Semiconductor Circuits and the Like—L. E. Barton. Assignee: Radio Corporation of America. A circuit employing semiconductor devices connected in cascade relationship that provides means for adjusting the bias voltages automatically to compensate for varying characteristics of different semiconductor devices thus permitting change of semiconductors without changing the source of bias voltage.

2,761,917 Class B Signal Amplifier Circuits—A. I. Aronson. Assignee: Radio Corporation of America. An amplifier utilizing an output stage and a driver stage connected in cascade direct-coupled relationship, each of said stages including a pair of transistors connected and biased for push-pull class B operation.

2,761,965 Electronic Circuits—A. H. Dickerson. Assignee: International Business Machines Corporation. A circuit which provides a plurality of serially arranged counter stages utilizing transistors in which each successive stage has a non-indicating, a primed and an indicating condition, said circuit being capable of operating as a quinary or biquinary counter.

2,762,001 Fused Junction Transistor Assemblies—J. S. Kilby. Assignee: Globe Union Inc. A transistor assembly including a metal container having a tinned tab and a terminal, an insulating base in said container, terminals rigidly fixed to said base, and a germanium wafer seated in a recess in said container and in contact with said tinned tab.

September 11, 1956

2,762,464 Train Speed Control System—C. S. Wilcox. Assignee: General Railway Signal Company. Train speed control apparatus for a speed control system comprising an axle driven frequency generator, an amplifying and high pass filtering circuit, means responsive to the voltage produced in the generator coil, and a keyed transistor oscillator having its intermittent output applied to said amplifying circuit.

2,862,730 Method of Making Barriers in Semiconductors—B. H. Alexander. Assignee: Sylvania Electric Products Incorporated. A method which comprises bringing a solid germanium body of one

(Continued on page 56)

* Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between May 1, 1959 and June 30, 1959

MANUFACTURERS

(In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Electricitäts-gesellschaft
AMP— Ampere Electronic Corp.
AEI— Associated Electrical Industries Export Ltd.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS-Electronics
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Laboratoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.

MUL— Mullard Ltd.
NTLB— Newmarket Transistors Ltd.
NPC— Nucleonics Products Co.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Sueddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TUN— Tung-Sol Electric, Inc.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P _c (mw)	DERAT ING °C/W	V _{cb}	V _{ce}	f _β (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2N699	3, 4, 5	NPNMe	S1	2000 \emptyset	75	120	80	100#	h_{FE} pulsed	40-120	FSC
2N710	2, 5	PNPD	Ge	300	250	15		250			TI
2N1011	3	PNPA	Ge		1.2	80		7Kc	$h_{FE}:I_C-3.0A$	53	DEL
2N1140	5	NPN	S1	1000		40	40	60	$h_{fe}:I_C-50ma$	50	TRA
2N1199	5	D	S1	100	125	20	20	147		25db	PHIL
2N1206	3	NPN	S1	1200		60	60		$h_{fe}:I_c-10ma$	35	TRA
2N1207	3	NPN	S1	1200		60	60		$h_{fe}:I_c-10ma$	50	TRA
2N1208	3	NPN	S1	85W	3.76	60	60	12	$h_{fe}:I_c-2.0A$	30	TRA
2N1209	3	NPN	S1	85W	3.76	45	45	12	$h_{fe}:I_c-2.0A$	40	TRA
2N1212	3	NPN	S1	85W	3.76	60	60	10	$h_{fe}:I_c-2.0A$	30	TRA
2N1228	2 \square	PNPF	S1	400	337	15	15	1.2	$h_{fe}:I_e-1.0ma$	14	HUG
2N1229	2 \square	PNPF	S1	400	337	15	15	1.2	$h_{fe}:I_e-1.0ma$	30	HUG
2N1230	2 \square	PNPF	S1	400	337	35	35	1.2	$h_{fe}:I_e-1.0ma$	14	HUG
2N1231	2 \square	PNPF	S1	400	337	35	35	1.2	$h_{fe}:I_e-1.0ma$	25	HUG
2N1232	2 \square	PNPF	S1	400	337	65	65	1.0	$h_{fe}:I_e-1.0ma$	14	HUG
2N1233	2 \square	PNPF	S1	400	337	65	65	1.0	$h_{fe}:I_e-1.0ma$	25	HUG
2N1234	2 \square	PNPF	S1	400	337	110	110	.80	$h_{fe}:I_e-1.0ma$	14	HUG
2N1238	3 \square	PNPF	S1	1000	150	15	15	1.2	$h_{fe}:I_e-1.0ma$	14	HUG
2N1239	3 \square	PNPF	S1	1000	150	15	15	1.2	$h_{fe}:I_e-1.0ma$	30	HUG
2N1240	3 \square	PNPF	S1	1000	150	35	35	1.2	$h_{fe}:I_e-1.0ma$	14	HUG

NOTATIONS

Under Use

- 1 - Low power a-f equal to or less than 50 mw
- 2 - Medium power a-f > 50 mw and equal to or less than 500 mw
- 3 - Power > 500 mw
- 4 - r-f/i-f
- 5 - Switching and Computer
- 6 - Low Noise
- 7 - Revised Spec.

Under Type

- A - Alloyed
- D - Diffused or Drift
- F - Fused
- G - Grown
- H - Hook Collector
- M - Microalloy
- Me - Mesa
- O - Other
- S - Surface Barrier
- UNI - Unijunction Transistor
- Y - Symmetrical
- i - Tetrode

Under Tab

- * Maximum Frequency
- # Figure of Merit
- Δ $f_{\alpha e}$
- \emptyset Minimum
- † Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_C

- \emptyset - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. { See code at end of chart }
				P _c (mw)	DERAT- ING °C/W	V _{CB}	V _{CE}	f _{αβ} (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2N1241	3	PNPF	S1	1000	150	35	35	1.2	$h_{fe}:I_E-1.0ma$	25	HUG
2N1242	3	PNPF	S1	1000	150	65	65	1.0	$h_{fe}:I_E-1.0ma$	14	HUG
2N1243	3	PNPF	S1	1000	150	65	65	1.0	$h_{fe}:I_E-1.0ma$	25	HUG
2N1244	3	PNPF	S1	1000	150	110	110	.80	$h_{fe}:I_E-1.0ma$	14	HUG
2N1247	1	NPN	S1	30	4000	6.0	6.0	5.0	$h_{fe}:I_E-100ua$	70	TRA
2N1248	6	NPN	S1	30	4000	6.0	6.0	5.0	h_{fe} at 1.0Kc	45	TRA
2N1249	6	NPN	S1	30	4000	6.0	6.0	5.0	h_{fe} at 1.0Kc	37	TRA
2N1252	3,4,5	NPNMe	S1	2000	75	30	20	100#	h_{FE} pulsed	15-45	FSC
2N1253	3,4,5	NPNMe	S1	2000	75	30	20	100#	h_{FE} pulsed	30-90	FSC
2N1254	5	PNPMe	S1	250	550	15	15	25	$h_{FE}:I_E-2.0ma$	15	HUG
2N1255	5	PNPMe	S1	250	550	15	15	25	$h_{FE}:I_E-2.0ma$	50	HUG
2N1256	5	PNPMe	S1	250	550	30	30	25	$h_{FE}:I_E-2.0ma$	15	HUG
2N1257	5	PNPMe	S1	250	550	30	30	25	$h_{FE}:I_E-2.0ma$	50	HUG
2N1258	5	PNPMe	S1	250	550	50	50	25	$h_{FE}:I_E-2.0ma$	15	HUG
2N1259	5	PNPMe	S1	250	550	50	50	25	$h_{FE}:I_E-2.0ma$	50	HUG
2N1267	5	D	S1	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1268	5	D	S1	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1269	5	D	S1	100	125	20	20	90*	At 4.3 Mc	25db	PHIL
2N1270	5	D	S1	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1271	5	D	S1	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1272	5	D	S1	100	125	20	20	200*	At 12.5 Mc	25db	PHIL
2N1275	2	NPNA	S1	386	350	100		.10	$h_{fe}:I_E-1.0ma$	14	RAY
2N1280	5	PNP	Ge	200	300	16	16	8.0	$h_{FE}:I_C-20ma$	60	IND
2N1281	5	PNP	Ge	200	300	16	12	10	$h_{FE}:I_C-20ma$	90	IND
2N1282	5	PNP	Ge	200	300	16	6.0	15	$h_{FE}:I_C-20ma$	100	IND
2N1284	5	PNP	Ge	200	300	20	15	8.0	$h_{FE}:I_C-10ma$	65	IND
2N1291	3	PNPA	Ge		3.0	35	30	.15	$h_{FE}:I_C-500ma$	40	CBS
2N1292	3	NPNA	Ge		3.0	35	30	.15	$h_{FE}:I_C-500ma$	30	CBS
2N1293	3	PNPA	Ge		3.0	60	60	.15	$h_{FE}:I_C-500ma$	40	CBS
2N1294	3	NPNA	Ge		3.0	60	60	.15	$h_{FE}:I_C-500ma$	30	CBS
2N1295	3	PNPA	Ge		3.0	80	80	.15	$h_{FE}:I_C-500ma$	40	CBS
2N1296	3	NPNA	Ge		3.0	80	60	.15	$h_{FE}:I_C-500ma$	30	CBS
2N1297	3	PNPA	Ge		3.0	100	100	.15	$h_{FE}:I_C-500ma$	40	CBS
2N1298	3	NPNA	Ge		3.0	100	80	.15	$h_{FE}:I_C-500ma$	30	CBS
2N1299	5	NPNA	Ge	150	.50	40	20	5.0	$h_{FE}:I_C-50ma$	110	SYL
2N1300	5	PNPMe	Ge	150	300	13	12	40	$h_{FE}:I_C-10ma$	50	RCA
2N1301	5	PNPMe	Ge	150	300	13	12	60	$h_{FE}:I_C-10ma$	50	RCA
2N1302	2	NPNA	Ge	150	400	25		3.0	$h_{fe}:I_C-20ma$	50	TI
2N1303	2	PNPA	Ge	150	400	30		3.0	$h_{fe}:I_C-20ma$	50	TI
2N1304	2	NPNA	Ge	150	400	25		5.0	$h_{fe}:I_C-20ma$	70	TI
2N1305	2	PNPA	Ge	150	400	30		5.0	$h_{fe}:I_C-20ma$	70	TI
2N1306	2	NPNA	Ge	150	400	25		10	$h_{fe}:I_C-20ma$	100	TI
2N1307	2	PNPA	Ge	150	400	30		10	$h_{fe}:I_C-20ma$	100	TI
2N1308	2	NPNA	Ge	150	400	25		15	$h_{fe}:I_C-20ma$	150	TI
2N1309	2	PNPA	Ge	150	400	30		15	$h_{fe}:I_C-20ma$	150	TI
2N1313	2,5	PNPA	Ge	175	350	30	20	12	$h_{FE}:I_C-400ma$	40	TUN
2N1316	5	PNP	Ge	200	300	30	15	15	$h_{FE}:I_C-1.0ma$	100	IND
2N1317	5	PNP	Ge	200	300	20	12	15	$h_{FE}:I_C-1.0ma$	95	IND
2N1318	5	PNP	Ge	200	300	10	6.0	15	$h_{FE}:I_C-1.0ma$	85	IND
2N1335	3,4	NPND	S1	2800	44	120	90	170	$h_{fe}:I_C-30ma$	13	PSI
2N1336	3,4	NPND	S1	2800	44	120	90	170	$h_{fe}:I_C-30ma$	13	PSI
2N1337	3,4	NPND	S1	2800	44	120	90	170	$h_{fe}:I_C-30ma$	13	PSI
2N1339	3,4	NPND	S1	2800	44	120	80	220*			PSI
2N1340	3,4	NPND	S1	2800	44	120	90	250*			PSI
2N1341	3,4	NPND	S1	2800	44	120	100	280*			PSI

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P _c (mw)	DERAT ING °C/W	V _{CB}	V _{CE}	f _{βB} (mc)	Gain		
									PARAMETER and (condition)	VALUE	
2N1343	5	PNP	Ge	200	300	20	16	6.0	$h_{FE}:I_C-50ma$	40	IND
2N1344	5	PNP	Ge	200	300	15	15	12	$h_{FE}:I_C-20ma$	90	IND
2N1345	5	PNP	Ge	200	300	10	8.0	12	$h_{FE}:I_C-400ma$	60	IND
2N1346	5	PNP	Ge	200	300	12	10	12	$h_{FE}:I_C-350ma$	125	IND
2N1347	5	PNP	Ge	200	300	20	12	8.0	$h_{FE}:I_C-10ma$	80	IND
2N1348	5	PNP	Ge	200	300	40	20	5.0	$h_{FE}:I_C-10ma$	95	IND
2N1349	5	PNP	Ge	200	300	40	35	10	$h_{FE}:I_C-10ma$	115	IND
2N1350	5	PNP	Ge	200	300	50	40	8.0	$h_{FE}:I_C-10ma$	95	IND
2N1351	5	PNP	Ge	200	300	40	30	8.0	$h_{FE}:I_C-10ma$	65	IND
2N1352	2	PNP	Ge	200	300	30	20	2.5	$h_{FE}:I_C-1.0ma$	70	IND
2N1353	5	PNP	Ge	200	300	15	10	3.5	$h_{FE}:I_C-10ma$	70	IND
2N1354	5	PNP	Ge	200	300	30	15	4.5	$h_{FE}:I_C-10ma$	70	IND
2N1355	5	PNP	Ge	200	300	30	20	8.0	$h_{FE}:I_C-10ma$	80	IND
2N1356	5	PNP	Ge	200	300	30	20	8.0	$h_{FE}:I_C-10ma$	80	IND
2N1357	5	PNP	Ge	200	300	30	15	12	$h_{FE}:I_C-10ma$	85	IND
2T3011	3	PNPA	Ge	12W	3.0	40	40	7Kc	$h_{FE}:I_C-1.0A$	70	SONY
2T3021	3	PNPA	Ge	12W	3.0	60	60	7Kc	$h_{FE}:I_C-1.0A$	70	SONY
2T3031	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C-1.0A$	32	SONY
2T3032	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C-1.0A$	50	SONY
2T3033	3	PNPA	Ge	10W	3.0	30	30	7Kc	$h_{FE}:I_C-1.0A$	80	SONY
2T3041		Matched Pair		2T3031							SONY
2T3042		Matched Pair		2T3032							SONY
2T3043		Matched Pair		2T3033							SONY
GFT20	2	PNPA	Ge	80	600	15		.60	$h_{fe}:I_e-1.0ma$	33	TKAD
GFT20R	2	PNPA	Ge	80	600	15		.60	$h_{fe}:I_e-1.0ma$	33	TKAD
GFT20/30	2,5	PNPA	Ge	80	600	30		.60	$h_{fe}:I_e-1.0ma$	33	TKAD
GFT20/60	2,5	PNPA	Ge	80	600	60		.60	$h_{fe}:I_e-1.0ma$	33	TKAD
GFT21	2	PNPA	Ge	80	600	15		1.1	$h_{fe}:I_e-3.0ma$	90	TKAD
GFT21R	2	PNPA	Ge	80	600	15		1.1	$h_{fe}:I_e-3.0ma$	90	TKAD
GFT21/30	2,5	PNPA	Ge	80	600	30		1.1	$h_{fe}:I_e-3.0ma$	90	TKAD
GFT21/60	2,5	PNPA	Ge	80	600	60		1.1	$h_{fe}:I_e-3.0ma$	90	TKAD
GFT22	2	PNPA	Ge	80	600	15		1.35	$h_{fe}:I_e-5.0ma$	150	TKAD
GFT22R	2	PNPA	Ge	80	600	15		1.35	$h_{fe}:I_e-5.0ma$	150	TKAD
GFT22/30	2,5	PNPA	Ge	80	600	30		1.35	$h_{fe}:I_e-5.0ma$	150	TKAD
GFT22/60	2,5	PNPA	Ge	80	600	60		1.35	$h_{fe}:I_e-5.0ma$	150	TKAD
GFT25	2	PNPA	Ge	80	600	15		.85	$h_{fe}:I_e-2.0ma$	50	TKAD
GFT25R	2	PNPA	Ge	80	600	15		.85	$h_{fe}:I_e-2.0ma$	50	TKAD
GFT25/30	2,5	PNPA	Ge	80	600	30		.85	$h_{fe}:I_e-2.0ma$	50	TKAD
GFT25/60	2,5	PNPA	Ge	80	600	60		.85	$h_{fe}:I_e-2.0ma$	50	TKAD
GFT31	2	PNPA	Ge	125	400	15		.40	$h_{fe}:I_e-30ma$	30	TKAD
GFT31/30	2,5	PNPA	Ge	125	400	30		.40	$h_{fe}:I_e-30ma$	30	TKAD
GFT31/60	2,5	PNPA	Ge	125	400	60		.40	$h_{fe}:I_e-30ma$	30	TKAD
GFT32	2	PNPA	Ge	125	400	15		.50	$h_{fe}:I_e-50ma$	50	TKAD
GFT32/30	2,5	PNPA	Ge	125	400	30		.50	$h_{fe}:I_e-50ma$	50	TKAD
GFT32/60	2,5	PNPA	Ge	125	400	60		.50	$h_{fe}:I_e-50ma$	50	TKAD

NOTATIONS

Under Use

- 1 - Low power a-f equal to or less than 50 mw
- 2 - Medium power a-f > 50 mw and equal to or less than 500 mw
- 3 - Power > 500 mw
- 4 - r-1/1-f
- 5 - Switching and Computer
- 6 - Low Noise
- 7 - Revised Spec.

Under Type

- A - Alloyed
- D - Diffused or Drift
- F - Fused
- G - Grown
- H - Hook Collector
- M - Microalloy
- Me - Mesa
- O - Other
- S - Surface Barrier
- UNI - Unijunction Transistor
- Y - Symmetrical
- I - Tetraode

Under *g:

- * Maximum Frequency
- † Figure of Merit
- Δ f_{ce}
- ∅ Minimum
- † Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

- ∅ - Infinite heat sink

(Concluded on next page)

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE { See Code Below }	TYPE { See Code Below }	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P _c (mw)	DERATING °C/W	V _{ce}	V _{ce}	f _β (mc)	Gain		
									PARAMETER and (condition)	VALUE	
GFT34	2	PNPA	Ge	125	400	15		.60	$h_{fe}:I_e - 75ma$	75	TKAD
GFT34/30	2,5	PNPA	Ge	125	400	30		.60	$h_{fe}:I_e - 75ma$	75	TKAD
GFT34/60	2,5	PNPA	Ge	125	400	60		.60	$h_{fe}:I_e - 75ma$	75	TKAD
GFT44/30	2,5	PNPA	Ge	63	800	30		10	$h_{fe}:I_e - 5.0ma$	100	TKAD
GFT45/30	2,5	PNPA	Ge	63	800	30		6.0	$h_{fe}:I_e - 2.0ma$	40	TKAD
GFT3008/20	3	PNPA	Ge		3.75	20		.25	$h_{FE}:I_C - 500ma$	33	TKAD
GFT3008/40	3	PNPA	Ge		3.75	40		.25	$h_{FE}:I_C - 500ma$	33	TKAD
GFT3008/60	3	PNPA	Ge		3.75	60		.25	$h_{FE}:I_C - 500ma$	33	TKAD
GFT3008/80	3	PNPA	Ge		3.75	80		.25	$h_{FE}:I_C - 500ma$	33	TKAD
GFT3408/20	3	PNPA	Ge		3.75	20		.30	$h_{FE}:I_C - 500ma$	60	TKAD
GFT3408/40	3	PNPA	Ge		3.75	40		.30	$h_{FE}:I_C - 500ma$	60	TKAD
GFT3408/60	3	PNPA	Ge		3.75	60		.30	$h_{FE}:I_C - 500ma$	60	TKAD
GFT3408/80	3	PNPA	Ge		3.75	80		.30	$h_{FE}:I_C - 500ma$	60	TKAD
OC169	4,5	PNPAD	Ge	50	600	20		70#	PG at .45Mc	35db	AMP
OC170	4,5	PNPAD	Ge	60	500	20		70#	PG at .45Mc	57db	AMP
OC171	4,5	PNPAD	Ge	60	500	20		100#	PG at 100Mc	11db	AMP
OD650	3	A	Ge		1.2	40	25	.10	$h_{FE}:I_C - 15A$	24	AEG
OD651	3	A	Ge		1.2	60	40	.10	$h_{FE}:I_C - 15A$	14	AEG
OD651a	3	A	Ge		1.2	60	30	.10	$h_{FE}:I_C - 15A$	24	AEG
OD750	3	A	Si		.80	100	50	1.0	$h_{FE}:I_C - 2.0A$	15	AEG
OD751	3	A	Si		.80	100	50	1.0	$h_{FE}:I_C - 5.0A$	15	AEG
OD760	3	A	Si		10	60	40	.50	$h_{FE}:I_C - 100A$	15	AEG
TK70	2	NPNA	Si	300	500	30		5.5	$h_{fe}:I_e - 3.0ma$	50	STCB
TK71	2	NPNA	Si	300	500	30		2.0	$h_{fe}:I_e - 3.0ma$	30	STCB
TK72	2	NPNA	Si	300	500	15		2.0	$h_{fe}:I_e - 3.0ma$	25	STCB
XC121	2	A	Ge	250	200	35	16				ESEB
XC131	2	A	Ge	250	100	35	16				ESEB
								Matched Pair			

Matched Pair

NOTATIONS

Under Use

- 1 - Low power a-f equal to or less than 50 mw
- 2 - Medium power a-f > 50 mw and equal to or less than 500 mw
- 3 - Power > 500 mw
- 4 - r-f/i-f
- 5 - Switching and Computer
- 6 - Low Noise
- 7 - Revised Spec.

Under Type

- A - Alloyed
- D - Diffused or Drift
- F - Fused
- G - Grown
- H - Hook Collector
- M - Microalloy
- Me - Mesa
- O - Other
- S - Surface Barrier
- UNI - Unijunction Transistor
- Y - Symmetrical
- z - Teletrode

Under f_{ab}

- * Maximum Frequency
- † Figure of Merit
- Δ I_{ce}
- g Minimum
- † Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

- ∅ - Infinite heat sink

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

CBS-Electronics: 2N235A, 2N235B, 2N236A, 2N236B, 2N242, 2N257, 2N285A, 2N297, 2N297A, 2N306, 2N312, 2N444, 2N445, 2N446, 2N447, 2N556, 2N558, 2N634, 2N635, 2N636, 2N1000

Hughes: 2N356, 2N357, 2N358, 2N388, 2N404, 2N425, 2N426, 2N427, 2N428

Industro: 2N381, 2N382, 2N383, 2N460, 2N461, 2N581, 2N584

Silicon Transistor Corp.: 2N1069, 2N1070

Sylvania: 2N109, 2N405, 2N407

Transitron: 2N117, 2N337, 2N338, 2N656

SEMICONDUCTOR CIRCUIT DESIGN

AWARDS RULES

1. Articles and nomographs published in Semiconductor products between April 1959 and March 1960 inclusive will be considered eligible for the awards. It is therefore advisable to submit manuscripts as soon as possible.

double-spaced, and submitted in duplicate. Illustrations and diagrams need not be inked or ruled; however they must be neatly prepared and legible.

2. Mail manuscripts to Semiconductor Products Magazine, 300 W. 43rd St., New York 36, N.Y. Attention: S. L. Marshall, Editor.

5. Judges' decision shall be final, and authors agree to accept these decisions as a condition of entry. Semiconductor Products reserves the right to correct typographical errors that may appear inadvertently in the manuscript.

Prizes will be 1) an engraved gold medal and \$500.00 for the most outstanding Semiconductor Circuit Design Article, and 2) an engraved gold medal and \$500.00 for the most outstanding Nomograph relating to Semiconductor Circuit Design.

6. Authors of all published material will be remunerated in accordance with our regular rates. Material found unacceptable will be returned to the authors.

4. Manuscripts are limited to 3,000 words or less, exclusive of illustrations and diagrams. Manuscripts should be typed

7. Employees of Cowan Publishing Corp. and affiliated companies, and members of their immediate families are not eligible for these awards.

NEW FROM PHILCO

HIGH FREQUENCY NPN SILICON DIFFUSED-BASE TRANSISTORS*

**30mc
PULSE RATE
SWITCHES**

**60mc
AMPLIFIERS**

Type Number	h_{fe}	Typical Power Gain	Typical Switching Times (Saturated Test Circuits)
2N1199	12-60 (DC)		t_r 35 m μ sec t_b 10 m μ sec t_f 25 m μ sec
2N1267	6-18	25 db at 4.3 mc	
2N1268	11-36		
2N1269	28-90		
2N1270	6-18	25 db at 12.5 mc	
2N1271	11-36		
2N1272	28-90		

Maximum V_{cb} —20 V
Maximum temperature—150° C
Maximum dissipation—100 MW

2N1199

This high speed switch has exceptionally low saturation voltage (typically 0.125 V), permitting *practical* design of 5 mc pulse circuits, using conventional saturated switching configurations. 30 mc pulse rates are obtainable in *practical* circuits using non-saturating techniques.

2N1267-68-69

The high gain characteristics of these units make possible the design of high efficiency IF amplifier circuits for communications equipment. These devices have unusually low collector capacitance . . . typically 1.5 μ f . . . and are available with restricted beta ranges to simplify design problems.

2N1270-71-72

The excellent high frequency response of these transistors makes practical the design of high performance communications systems at frequencies up to 60 mc. They have the same low collector capacitance and are available with restricted beta ranges.

Immediately available for prototype design from your Philco Industrial Semiconductor Distributor.

Write Dept. SC959 Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa.

*SADT . . . Trademark Philco Corp. for Surface Alloy Diffused-base Transistor.

Circle No. 19 on Reader Service Card

PHILCO

LANSDALE TUBE COMPANY DIVISION
LANSDALE, PENNSYLVANIA



Lepel

HIGH FREQUENCY INDUCTION HEATING UNITS



The Lepel line of induction heating equipment represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for numerous industrial applications.

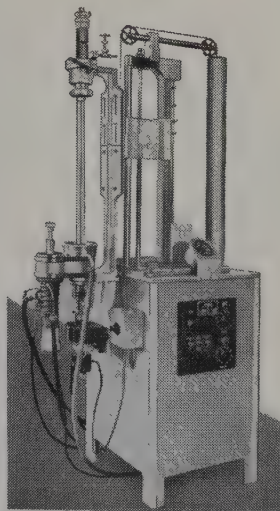
If you are interested in induction heating you are invited to send samples of the work with specifications. Our engineers will process and return the completed job with full data and recommendations without any cost or obligations.

FLOATING ZONE FIXTURE FOR METAL REFINING AND CRYSTAL GROWING

A new floating zone fixture for the production of ultra-high purity metals and semi-conductor materials. Purification or crystal growing is achieved by traversing a narrow molten zone along the length of the process bar while it is being supported vertically in vacuum or inert gas. Designed primarily for production purposes, Model HCP also provides great flexibility for laboratory studies.

Features

- A smooth, positive mechanical drive system with continuously variable up, down and rotational speeds, all independently controlled.
- An arrangement to rapidly center the process bar within a straight walled quartz tube supported between gas-tight, water-cooled end plates. Placement of the quartz tube is rather simple and adapters can be used to accommodate larger diameter tubes for larger process bars.
- Continuous water cooling for the outside of the quartz tube during operation.
- Assembly and dis-assembly of this system including removal of the completed process bar is simple and rapid.



Model HCP

Electronic Tube Generators from 1 kw to 100 kw.
Spark Gap Converters from 2 kw to 30 kw.

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information.



All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

LEPEL HIGH FREQUENCY LABORATORIES, INC.

55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

Circle 20 on Reader Service Card

Announcement

SEMICONDUCTOR PRODUCTS
will publish a Limited Printing
(1000 Copies) of the

Second Conference Symposium

on Nuclear Radiation Effects on Semiconductor Devices, Materials, and Circuits



This conference is sponsored by the Working Group on Semiconductor Devices of the Advisory Group on Electron Tubes, Dept. of Defense and will be held at the Western Union Auditorium, 60 Hudson St., New York City, on Sept. 17 and 18, 1959.



To insure yourself of a bound copy of these proceedings you are urged to fill out the reservation form provided at the bottom of this page. The price of this book is \$4.50.

Following is a list of the papers scheduled to be delivered at this conference:

- High Energy Electron Irradiation of Germanium and Silicon
- The Nature of a Non-equilibrium Excess Conductance Induced in Silicon by Nucleon Irradiation
- Transient Radiation Effects in Semiconductors
- Positive Ion Bombardment of Metals with Radioactive Kr-85
- Radiation Effects in Compound Semiconductors
- Electron Irradiation Effects in CdS
- Minority Carrier Lifetime of Neutron Bombarded Germanium
- Correlation of Theoretical and Experimental Behavior of Silicon Junction Diodes During Neutron and Gamma Irradiation
- Study Directed Toward Improving the Radiation Tolerance of Silicon Diodes
- Preliminary Study of the Effects of Exposure of Electronics Components to 2-Mev Electrons and Other Kinds of Radiation
- Radiation Effects on Semiconductors
- The Effects of Nuclear Radiation on Some Selected Semiconductor Devices
- Room Temperature Operated Solid State Device for Charged Particle Detection
- Gamma Irradiation Effects on Infrared Detectors
- On The Neutron Bombardment Reduction of Transistor Current Gain
- Analysis of Simple Rectifying and Magnetic Amplifier Circuits During Irradiation
- Transistor Circuit Behavior at Exposures Greater than 10^{15} Fast Neutrons/CM²
- Radiation Resistant Digital Computer Circuitry
- The Use of Diffused Junctions in Silicon as Fast Neutron Dosimeters
- A Transistor Scaler Circuit For A Megarad Gamma Ray Environment
- Problems of Correlating Radiation Environments
- The Effect of Intermittent Irradiation of the Magnetic Remanence of a Ferrite

ORDER BLANK

SEMICONDUCTOR PRODUCTS, Dept. C
300 West 43rd Street
New York 36, N.Y.

Sirs: Enclosed is my check for \$4.50 ☐

Bill me for \$4.50 ☐

Bill company ☐

Name Company

Address

City Zone State

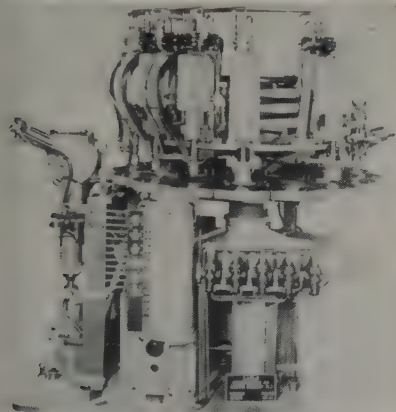
New

Products

Automatic Hole Puncher

The principles of automatic production built into the new Kahle Engineering Company Automatic Hole-Punching Machine #3013 will quite likely find use in many industries where high-speed hole-punching and fire glazing are applied to glass units on any configuration. Has a capacity of 2000 sealed beam headlamp reflectors per hour; punches multiple pre-formed holes, fire-glazes the holes and unloads the reflectors to an annealer. Can be fully synchronized with the press to provide any timing cycle desired. The two-position punching operation performed at 2400 psi at 400° C can be altered to vary the hole pattern, number or size to suit manufacturers' specs. Occupies 5 x 5 ft. floor space, is 6'6" high, approx. 6000 lbs. Can be driven from the forming press or may be equipped with its own power drive. Request data sheet 3'13.

Circle 132 on Reader Service Card



Aluminum Wafers

Hard-anodized aluminum insulator wafers characterized by excellent dielectric resistance and thermal conductivity have been developed for use with power transistors requiring electrical insulation from chassis and dissipation of the substantial heat generated at rated capacities. In diamond, round and square shapes to suit all bases, the aluminum wafers are installed between transistor and chassis, heat sink or other surfaces on which the transistor is mounted. Manufactured by Monadnock Mills, subsidiary of United-Carr Fastener Corporation.

Circle 116 on Reader Service Card



Package System Teamwork

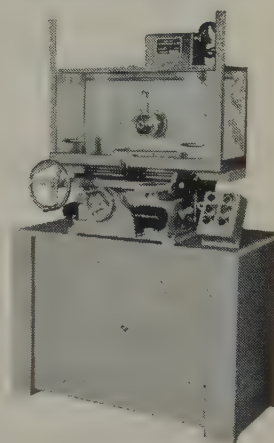
Micro-Matic

PRECISION WAFERING MACHINES

Models for all jobs requiring very thin slicing of semi-conductor and other difficult-to-cut materials.

Model WMA

Fully automatic, produces wafers consistent in thickness and parallelism to within .0005" total variation.



Optical ORIENTATION SYSTEM

EFFICIENT. Visual undistorted pattern allows immediate adjustment. Requires no interpretation or correlation with charts and data.

PRACTICAL. Safe and simple to handle. Always ready for immediate use. Compact—takes up only two square feet of table surface.

ECONOMICAL. Low cost, self contained unit. Uses no film or expendable accessories. No maintenance required.

for laboratory or production use

Micromech's experienced Engineering Department is at your service in developing an optical orientation system to meet your particular requirement.

Write for illustrated brochures



MICROMECH MANUFACTURING CORP.

A Division of Sanford Manufacturing Corp.

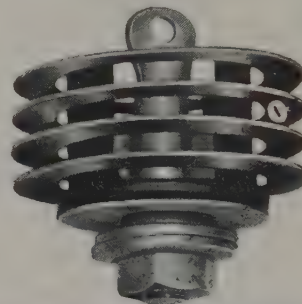
1020 COMMERCE AVE., UNION, N.J.

Circle No. 39 on Reader Service Card

for maximum reliability

PREVENT THERMAL RUNAWAY

Prevent excessive heat from causing "thermal runaway" in power diodes by maintaining collector junction temperatures at, or below, levels recommended by manufacturers, through the use of new Birtcher Diode Radiators. Cooling by conduction, convection and radiation, Birtcher Diode Radiators are inexpensive and easy to install in new or existing equipment. To fit all popularly used power diodes.



with NEW BIRTCHER DIODE RADIATORS

B

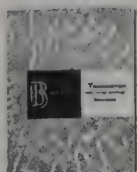
BIRTCHER COOLING AND RETENTION DEVICES ARE NOT SOLD THROUGH DISTRIBUTORS. THEY ARE AVAILABLE ONLY FROM THE BIRTCHER CORPORATION AND THEIR SALES REPRESENTATIVES

THE BIRTCHER CORPORATION industrial division

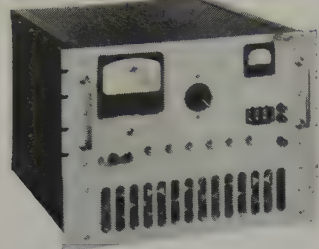
4371 Valley Blvd. Los Angeles 32, California

Sales engineering representatives in principal cities.

Circle No. 21 on Reader Service Card



FOR CATALOG and test data write:



CURRENT GOVERNOR

Model CG-12

for **Constant Current**

- Precision Current Regulator
- Diode Tester

► High Current

► Excellent Regulation

► Programmable

For testing and measurement of transistors, diodes, meters, other current sensitive devices.

- Current Range is 50 ma-30 amp
- Regulation—0.05%
- Voltage 0-15

In use by leading companies for transistor test, diode test, calibration.

Literature describing this and other constant current sources from 0.1µa to 30 amp. may be obtained from



Circle No. 22 on Reader Service Card

ELINEX

Confidential

Initial Contacts

and

Preliminary Negotiations

for

- Acquisitions
- Mergers
- Issues
- Financing

Confidential Listings

ELINEX

Electronics Industries Exchange

Suite 1001

15 Maiden Lane

New York 38, N. Y.

WO 4-1530

Circle No. 37 on Reader Service Card

WANTED TO BUY NEW SURPLUS TRANSISTORS, DIODES RECTIFIERS, ETC.

We specialize in disposing of surplus semiconductor devices, and can offer the highest cash return for your idle inventory.

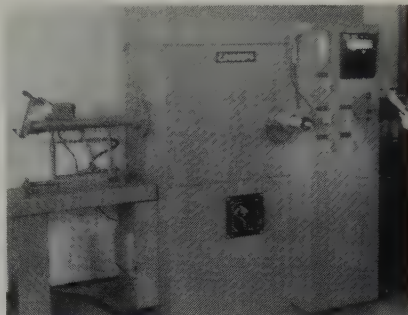
Electronic Laboratory Supply Co.,
7208 Germantown Ave., Phila. 19, Pa.

Circle No. 38 on Reader Service Card

Graphite Tube Furnace

A new high temperature graphite tube furnace has been announced by the Pilot Plant Equipment Division of Lindberg Engineering Company. Type TR25-212C18 has been developed to meet the demands generated by the metals, ceramic and petroleum industries for controlled high temperatures. The overall operating temperature range of 1600 to 5000°F. makes it suitable for a variety of applications including: Sintering of powder metals, High temperature investigations and firing of ceramic bodies, High temperature chemical reactions for the petroleum industry.

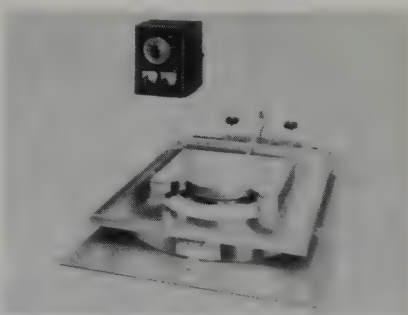
Circle 104 on Reader Service Card



Etching Machine

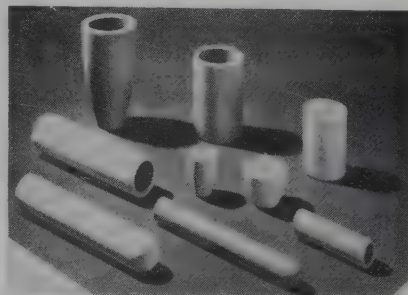
Carman Laboratories announces a new machine for etch-cleaning transistors, rectifiers, diodes & other small parts. Partially completed electronic components are placed in a moving carrier especially designed to expose corroded or oxidized parts to an array of liquid jets. These jets etch-clean and rinse surface contamination from the exposed parts. Processes 1200 to 2400 units per hour. Requires 30" x 22" table-top area and 115 volts A.C.

Circle 133 on Reader Service Card



Pure Oxide Ceramics

Materials for Electronics, Inc., announces Degussit ceramics in pure sintered alumina, sintered spinel, sintered zirconium oxide (stabilized), sintered magnesium oxide and kaolin bonded corundum. These top products of oxide ceramics meet the highest thermal, chemical, mechanical and electrical requirements. Insulating parts made from the pure alumina body (A1-23) are sintered



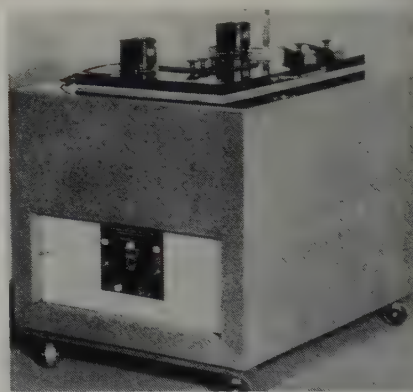
into shapes without the addition of any sintering auxiliaries. The boron content of A1-23 is less than one part per million which makes it suitable for processing of semiconducting materials. The pure alumina body can be delivered in the form of discs, rings, tubes, boats, crucibles as well as special shapes.

Circle 107 on Reader Service Card

Testing Baths

Labline, Inc., has announced production of a new line of variable temperature baths to test diodes, electronic components, thermostats, and other equipment that requires highly accurate testing conditions. These conditions are secured with thermistor controls capable of maintaining temperatures within $\pm 0.1^\circ\text{C}$ accuracy. Product Temp Baths may be had as individual units each adjustable to 100°C , 25°C , or -55°C ; or as a combination with a temperature range from 100°C to -55°C .

Circle 122 on Reader Service Card



Magnifying Lamp

Designed for precision seeing, the Luxo Magnifying lamp, designated Model FLM-1, combines large magnification, cool fluorescent light, and maneuverability into one versatile unit. Features a large precision ground lens with excellent distortion-free 4X magnification. Can be raised, lowered, tilted or turned to any angle to put magnification and cool light where you want it. Leaves both hands free for the job. Fixture is easily turned out of the way when not in use.

Circle 112 on Reader Service Card



Mesa Transistors

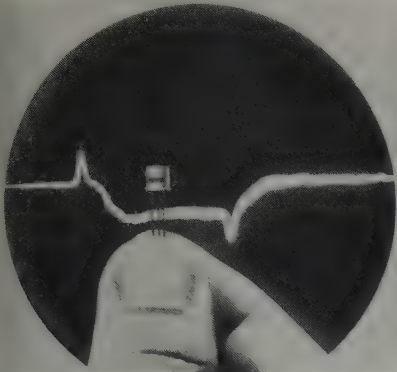
Fairchild announces the 2N699, a high voltage NPN diffused silicon mesa transistor. This two watt unit is rated at 120 volts collector to base, permitting wide voltage swings in amplifier and oscillator circuits. Typical gain-band width product of 120 mc gives excellent broadband video response.

Circle 131 on Reader Service Card

Mesa Switching Transistor

Availability of a new ultra-fast diffused-base silicon "mesa" switching transistor was announced by Texas Instruments Incorporated. Features typical total switching speeds as fast as 25 millimicroseconds. The 2N702 is produced by the gaseous-diffusion process. Dissipates 150 milliwatts at 100° in free air. Provides a guaranteed DC beta spread of 15 to 45 and a maximum collector cutoff current of 0.5 microamps. Minimum breakdown voltage (BV_{CEO}) is 20 volts and maximum saturation voltage is 0.6 volts. It measures only 0.225 inches maximum diameter and 0.205 inches in height not including the 0.520-inch leads.

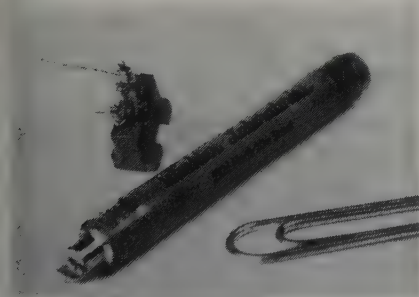
Circle 110 on Reader Service Card



Subminiature Wire Wrapper

This new tool makes reliable wrapped connections to subminiature sockets and transistor sockets and is available from Winkler Laboratories. It is vastly superior to such items as long-nose pliers and tweezers. It can do a better job faster. Connections are uniform, neat and highly reliable. It will accommodate all wire sizes compatible with subminiature terminal size and spacings including #26 AWG and smaller.

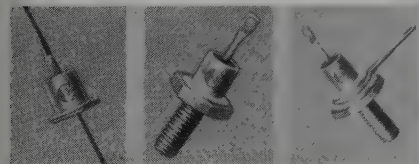
Circle 117 on Reader Service Card



Diffused Silicon Rectifiers

Columbus Electronics Corp., has announced the availability, in production quantity, of its new 2000 Volt PIV double diffused silicon rectifiers. Available in the axial lead top hat, 7/16" stud and insulated stud mounts, hermetically sealed. Power supply, magnetic amplifier and blocking applications are listed as typically suitable applications. Specification features include: 1400 to 2000 V. PIV; up to 10 amps rectified current; 1uA leakage at 25°C; 2 V forward drop at 25°C.

Circle 115 on Reader Service Card



Metallurgists & Specialists in Unusual Products...

High-Purity METALS *for* Semi-Conductor Devices

GOLD

doped with N-type or P-type elements—supplied in form of wire, sheet or ribbon and cut or stamped pieces.



CHEMICALLY-PURE ALUMINUM WIRE

As small as .002"
(approximate)

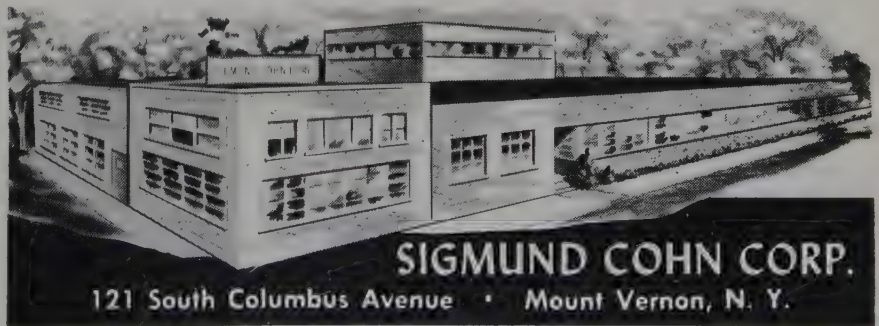
INDIUM

electroplated
base or precious
metal wires.

SINCE 1901



Write for list of products



SIGMUND COHN CORP.

121 South Columbus Avenue • Mount Vernon, N. Y.

Circle No. 23 on Reader Service Card



RCA

CREATES A

GOLDEN OPPORTUNITY

**FOR SCIENTISTS
ENGINEERS**

Inquiries are invited for key openings at RCA's new, ultra-modern Semiconductor and Materials headquarters in suburban Somerville, New Jersey (just 35 miles from New York City), from individuals with degrees in . . .

**PHYSICS • ELECTRICAL ENGINEERING • PHYSICAL CHEMISTRY
INORGANIC CHEMISTRY • METALLURGY**

RCA-Somerville is headquarters for major research and development work on:

SEMICONDUCTORS

Silicon Rectifiers • High Power Transistors • Diodes

MATERIALS

Intermetallics • Thermoelectrics • Semiconducting
Oxide Films

MICROMODULES

Subminiature Circuit Design • Component Development

PHONE OR WRITE: MR. J. B. DALY, RAndolph 2-3200

Dept. SE-60



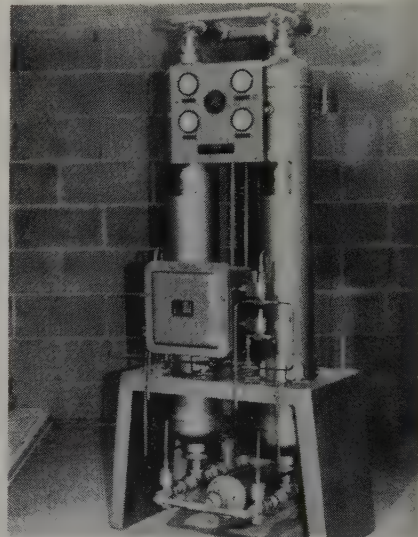
RADIO CORPORATION OF AMERICA
SEMICONDUCTOR AND MATERIALS DIVISION, SOMERVILLE, NEW JERSEY



Heatless Air Dryer

Completely automatic, heatless desiccant dryers capable of producing dry air to -200°F dewpoint, are now available for manufacturers of semiconductors, or other electronic assemblies requiring the use of dry-box assembly techniques. The use of dry air completely eliminates the cost and maintenance of the usual bottled gas systems. Trinity Equipment Corporation, manufacturers of Heat-Less dryers and pressurization systems, announce a complete line of dryer units, and complete pressurization systems for the dry-box assemblers.

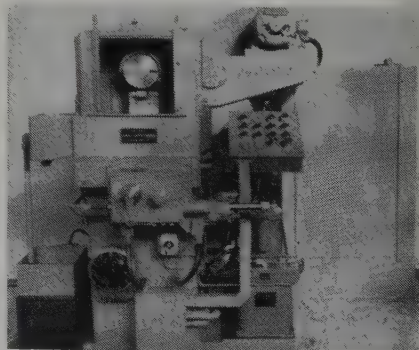
Circle 106 on Reader Service Card



Automatic Slicing Machine

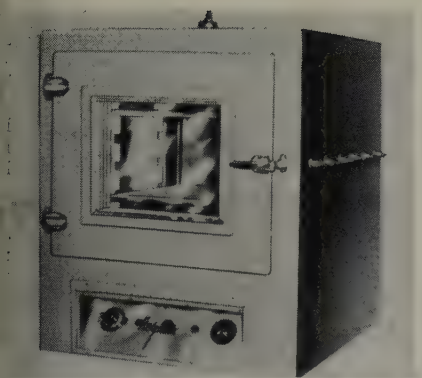
A fully automatic high production machine for slicing semiconductor crystals has recently been developed by the Fitchburg Engineering Corporation. Machine will slice an ingot section up to 4" in length completely automatically. Crystal thicknesses down to .007" plus or minus .0005" are obtainable. All motions may be made independently by hand if desired for special work such as individual rate-grown wafers, etc. Safety interlocking is provided. Hand-Auto selector switch may be locked with a key in Auto position, thus disabling set-up controls. Weighs approximately 2800 pounds.

Circle 109 on Reader Service Card



Forced Draft Oven

Designed with a temperature to 535°F , Electric Hotpack Company forced draft oven is suitable for diode age cycling, drying of transistors and printed circuits, encapsulation, short heat tests and many other temperature conditioning processes for electrical and electronic parts. Standard equipment includes thermostat, wattage selector heat switch and thermometer. Independently circuited over-temperature controller, designed to pro-



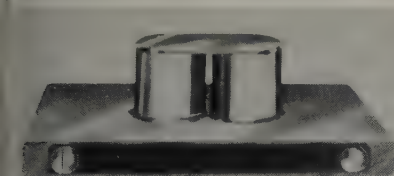
fect work load from accidental heat damage is available. Thru wall terminals optional.

Circle 121 on Reader Service Card

Thermoelectric Junction

Ohio Semiconductors announces a new device, Thermo-cell, type TA-11, thermoelectric junction designed for applications where it is desired to maintain a temperature which is either above or below the ambient. Control applications such as quartz crystal ovens, critical electrical circuits, biological specimens and many other applications where relatively low heat input or extraction is involved, are ideal for the Thermo-cell. Can be used for cooling, heating, power generation and dynamic heat transfer.

Circle 118 on Reader Service Card



Pyro Fuze Wire

A wire has been developed by Sigmund Cohn Corp. which, when heated to about 650°C either by passing current thru it or otherwise, ignites with explosive violence and reaches a temperature of about 2000°C. The total energy developed as heat far exceeds the energy necessary for the initial ignition. The wire is strong and ductile, having a sufficiently high tensile strength that it may easily be handled in most manufacturing operations. B3 Pyro Fuze Wire consists of two separate metals between which an exothermic alloying reaction takes place after a critical temperature has reached. Since it is available in a wide range of sizes to as small as .001", it should be well suited to many special applications including fuze or detonator devices.

Circle 130 on Reader Service Card

BACK ISSUES AVAILABLE

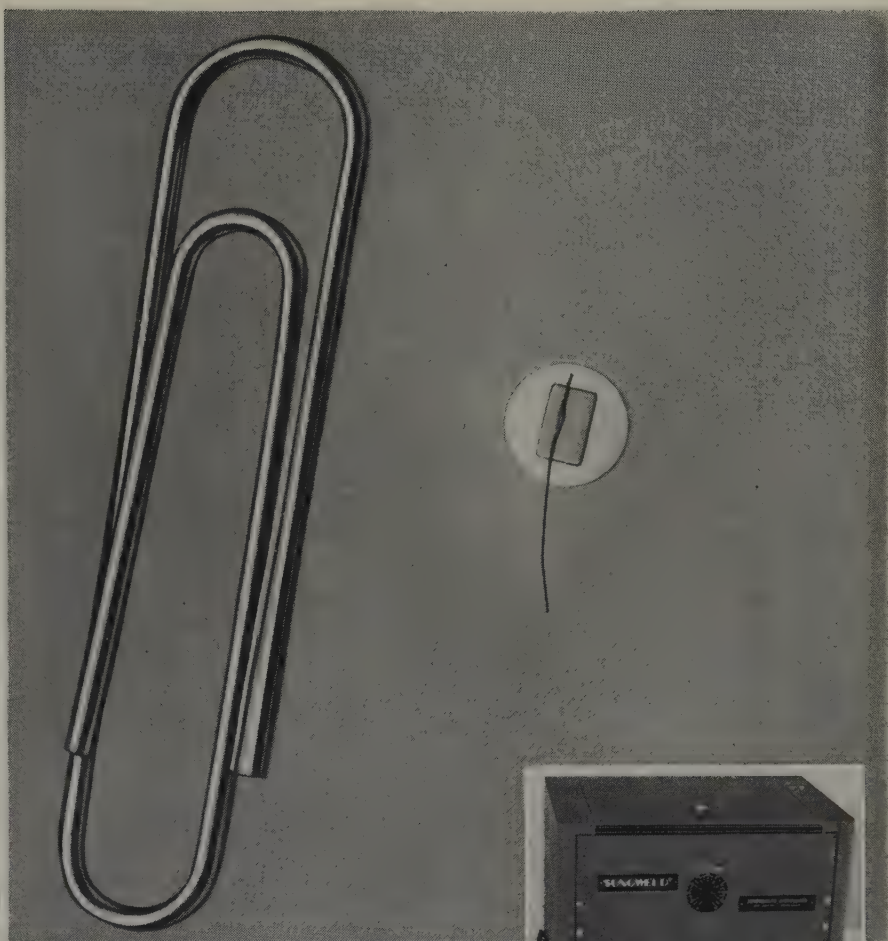
75¢ each

1958—Jan/Feb; March/April;
May/June; Nov/Dec.

1959—March; May; June;
July; Aug.

SEMICONDUCTOR PRODUCTS

Back Issue Dept.
300 W. 43 St. New York, N. Y.



Above: Photographic enlargement showing .005" aluminum wire to silicon wafer achieved by ultrasonic welding resulting in low ohmic contact and no penetration. Paper clip shows relative size.

Right: 100-watt SONOWELD unit, Model W-100-TSL-58-6 designed specifically for welding small semiconductor components. Generator size, 22x14x15 inches.



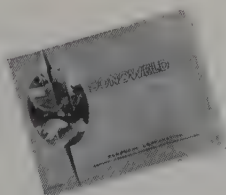
Semiconductor Assembly INCREASE PRODUCTION YIELD BY ULTRASONIC WELDING

Ohmic contact between aluminum or gold leads and silicon or germanium can be obtained with high reproducibility, using SONOWELD, the ultrasonic welding tool for precision work. No current passes thru the weld, therefore no spark or sputter. There is no melting, no contamination. The process and equipment readily lends itself to automation. Reproducibility results in high production yield.

You get efficient, reliable welds in components that operate successfully over a wide range of ambient temperatures in industrial and military applications. Use SONOWELD for precision ultrasonic welding of fine parts.

SONOBOND CORPORATION
West Chester, Pa. • Telephone: OWen 6-4710
A Subsidiary of Aeroprojects, Incorporated

Larger SONOWELD units are also available. If you want to evaluate this new and exclusive ultrasonic welding technique, let us send you additional information. Ask for Bulletin 118.



SONOWELD®

Circle No. 24 on Reader Service Card

SAVE MONEY

Subscribe to SEMICONDUCTOR PRODUCTS Buy Group Subscriptions!

When 5 or more individual one year subscriptions are purchased and pre-paid at one time a substantial savings results. On this basis each subscriber pays only \$5.00 for a 12 issue subscription instead of \$6.00.

When 5 or more individuals each purchase 2 year subscriptions, each subscriber saves \$2.00 by paying \$8.00 per subscription instead of \$10.00. (Present subscribers may extend their subscription and still use the scale shown above). Under the Group Subscription Plan each subscriber's order must be filled out completely. Sign up a Group.

Group Subscriptions Can Only Be Accepted from U.S. Subscribers

- ☐ 1 year subscription
☐ 2 year subscription

- ☐ New subscription
☐ Subscription extension

1

Sirs: Please enter Group subscriptions to Semiconductor Products for the following:

Name Position

Company Dept.

Address

City Zone State

Products Mfd.

Please send my magazines to (if some other address)

Address

City Zone State

- ☐ 1 year subscription
☐ 2 year subscription

- ☐ New subscription
☐ Subscription extension

2

Name Position

Company Dept.

Address

City Zone State

Products Mfd.

Please send my magazines to (if some other address)

Address

City Zone State

- ☐ 1 year subscription
☐ 2 year subscription

- ☐ New subscription
☐ Subscription extension

3

Name Position

Company Dept.

Address

City Zone State

Products Mfd.

Please send my magazines to (if some other address)

Address

City Zone State

- ☐ 1 year subscription
☐ 2 year subscription

- ☐ New subscription
☐ Subscription extension

4

Name Position

Company Dept.

Address

City Zone State

Products Mfd.

Please send my magazines to (if some other address)

Address

City Zone State

- ☐ 1 year subscription
☐ 2 year subscription

- ☐ New subscription
☐ Subscription extension

5

Name Position

Company Dept.

Address

City Zone State

Products Mfd.

Please send my magazines to (if some other address)

Address

City Zone State

PATENT REVIEW

(from page 44)

conductivity type into contact with molten mixture containing an activator impurity of the opposite conductivity type and maintaining said engagement for a time sufficient to convert a surface said body to the opposite conductivity type.

2,762,867 Subscriber Telephone Circuit—L. A. Meacham. Assignee: Bell Telephone Laboratories. A subscriber telephone circuit of the anti-sidetone type having a semiconductor amplifier in the line circuit and a balancing semiconductor amplifier in the anti-sidetone circuit of the set.

2,762,870 Push-Pull Complementary Type Transistor Amplifier—G. C. Sziklai, R. L. Lohman, A. A. Barco. Assignee: Radio Corporation of America; In combination with a pair of semiconductor devices of opposite conductivity type, means for applying a signal voltage of the same instantaneous polarity to the input electrodes and means providing a biasing voltage between the common electrodes for controlling the operation of said devices in balanced relation.

2,762,873 Transistor Bias Circuit Stabilization—H. C. Goodrich. Assignee: Radio Corporation of America. A semiconductor amplifier circuit utilizing a semiconductor device which exhibits the characteristic of providing a phase reversal between the base and collector electrodes.

2,762,874 Semiconductor Signal Amplifier Circuits—A. A. Barco. Assignee: Radio Corporation of America. A semiconductor signal amplifying device that provides substantially balanced output signal.

2,762,875 Stabilized Cascade-Connected Semiconductor Amplifier Circuits And The Like—J. T. Fisher. Assignee: Radio Corporation of America. A circuit arrangement employing a plurality of cascade-coupled semiconductor devices whereby both the emitter electrode biasing resistors and the impedance of the supply source are bypassed for signal frequencies.

2,762,921 Binary Trigger Circuit—R. A. Henle. Assignee: International Business Machines Corporation. A circuit comprising a bistable circuit, input and output branches, and means effective upon receipt of a signal predetermined polarity at said input branch to shift said output branch from a low to a high output state.

2,762,953 Contact Rectifiers and Methods—I. Berman. Assignee: Sylvania Electronic Products Incorporated. An area rectifier including a layer of highly purified germanium, a layer of metal of group III on one surface thereof and an area contact on the opposite surface thereof of a material different from said layers.

2,762,954 Method For Assembling Transistors—M. Leifer. Assignee: Sylvania Electronic Products Incorporated. A body of semiconductive material incorporating an upstanding rib between laterally extending surfaces on a base portion, a large area contact engaging said body, and a pair of whiskers engaging said rib from opposite sides, said rib being sufficiently thin to enable interaction between said whiskers.

2,862,955 Transistor Electrode Contacts—G. B. Herzog, G. C. Sziklai. Assignee: Radio Corporation of America. A device comprising a body of semiconductor material, a plurality of electrodes in operative relation with said body and a lead connected to each of said electrodes, said leads being of unequal length to insure selective application of voltages to said leads while the device is being inserted in an operating circuit.

2,762,956 Semiconductor Devices And Methods—R. C. Ingraham. Assignee: Sylvania Electric Products Incorporated. A device comprising a base, leads integrally molded therewith, a whisker element directed away from said base and a semiconductive body carried by a support, said body being engaged by said whisker in point-contact and with a predetermined contact pressure.

2,762,957 High Conduction Diode—B. J. Rothlein. Assignee: SEP. A rectifier including a body of *n*-type germanium, a wire and a quantity of metal particles confined under pressure between at least part of the end surface of the wire and the germanium.

September 18, 1956

2,763,726 Telephone Ringing-Signal Transmission System—D. C. Weller. Assignee: Bell Telephone Laboratories. A telephone system for transmission between a balanced voice-frequency line at an office terminal and a balanced multiparty voice-frequency at an outlying terminal.

2,763,731 Semiconductor Signal Translating Devices—W. G. Pfann. Assignee: Bell Telephone Laboratories. A device comprising a body of semiconductive material-contact a *p-n* type construction; two point-contact electrodes on opposite sides of the junction and positioned in such close proximity thereto that the carriers injected by the first electrode directly control the flow of carriers to the second electrode; and a third electrode making an ohmic connection with the zone to which the first electrode is connected.

2,763,771 Single Phase Rectifier Arc Welder—H. J. Bischel. Assignee: Westinghouse Electric Corporation. Arc welding apparatus including a main rectifying circuit, an auxiliary rectifier circuit, said auxiliary circuit being dimensioned to supply current of substantially smaller magnitude than that supplied by the main rectifier so that when current from said main circuit tends to drop below a predetermined magnitude current is maintained through said auxiliary circuit.

2,763,780 Binary Frequency Divider—C. W. Skelton, J. S. Mason. Assignee: Texas Instruments Incorporated. A multiple stage frequency divider circuit in which each basic stage includes a transistor, a resistor, a capacitor, and a saturable transformer, said circuit being well suited for cascade connection to derive consecutive half-multiples of an input frequency.

2,763,822 Silicon Semiconductor Devices—F. V. Frola, M. W. Slye. Assignee: Westinghouse Electric Corporation. A device comprising a silicon semiconductor, a contact member composed of a metal selected from the group consisting of molybdenum, tungsten, and base alloys, said contact member being disposed adjacent to said semiconductor; and a fused layer between said contact and said semiconductor.

ENGINEERS
Chemical • Electronic • Mechanical
PHYSICISTS • PHYSICAL CHEMISTS • METALLURGISTS

Achieve Best Use of Your Creative Talents with General Electric in SEMICONDUCTORS

At G.E. you will . . .

- ☐ Work in the campus-like environment of modern Electronics Park.

Associate and work with GE's outstanding scientists and engineers—Who for example are leading the industry in the development of such "revolutionary" devices as the TUNNEL DIODE and the SILICON CONTROLLED RECTIFIER.

- ☐ Be supported by the company's ample financial resources and complete research facilities.

Challenging Openings In:

SEMICONDUCTOR APPLIED RESEARCH

Intriguing problems and challenging studies on: (1) diffusion and vapor deposition; (2) stabilization of semiconductor devices; (3) multijunction switching structures; (4) tunnel diodes in germanium and silicon; (5) surface conditioning problem in germanium, silicon and compounds; (6) silicon carbide studies; (7) energy conversion devices; (8) development of new semiconductor materials.

DEVICE DESIGN AND PROCESS DEVELOPMENT

Develop chemical and metallurgical processes for the fabrication of germanium and silicon "mesa" type transistors, NPNP switching structures, silicon controlled rectifiers, tunnel diodes, and other new semiconductor devices. Perform device design and structure analysis.

Semiconductor Materials Engineering
Test Equipment Design & Development
Quality Control Engineering
Production Tool & Equipment Design & Development

U.S. Citizenship Not Required

- ☐ Enjoy gracious living in the heart of New York's Vacationland . . . adjacent to the famed Finger Lakes Region, Adirondack Mountains, and the Thousand Islands.

Liberal relocation allowances. Outstanding benefit plans include tuition refund for graduate studies at Syracuse University.

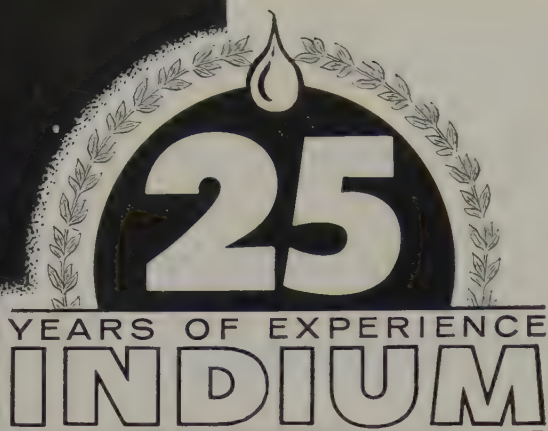
Write in strict confidence to:

Mr. M. D. Chilcote, Div. 125-M1

SEMICONDUCTOR PRODUCTS DEPT.

GENERAL  ELECTRIC

Electronics Park, Syracuse, New York



25 YEARS OF EXPERIENCE INDIUM

1934-1959

- AIDS LUBRICATION
- UNIQUE STABILIZATION
- ALLOYS READILY

QUALITY

at the Indium Corporation of America means purity of metals, and strict adherence to specifications.

SERVICE

means prompt delivery to customers, and technical help in specific uses of Indium.

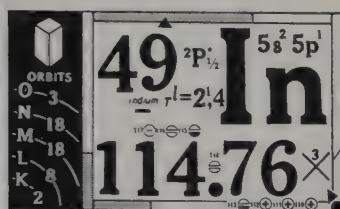
RESEARCH

means "forward looking" with respect to new products and new techniques.

Since 1934 when the Indium Corporation was formed and produced the first commercial amounts of Indium, we have gained in knowledge and in service to all the varied users of Indium in its almost limitless applications and forms.

Why not write us today . . . our years of research and experimentation, our pioneer developments, our experience in producing Indium to the exact specifications of our customers, our many technical helps are at your service.

Commercial quantities are available in Indium metal (specially refined 99.999% pure or 99.97% pure), Indium wire, foil, ribbon, pellets, spheres or powders. Also "Indalloy" intermediate solders and other high purity metals.



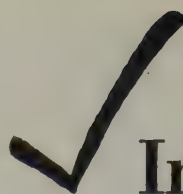
Write to Dept. S-759 for Indium booklet: "INDALLOY" Intermediate Solders."

THE INDIUM

CORPORATION OF AMERICA

1676 Lincoln Avenue • Utica, New York
Since 1934 . . . Pioneers in the Development and Applications of Indium for Industry.

Circle No. 25 on Reader Service Card



Industry News

CONFERENCE CALENDAR

The Following October 1959 IRE and Jointly Sponsored Meetings Are Scheduled:

- Sept 30 Oct 1 Industrial Electronics Symposium, Mellon Institute, Pittsburgh, Pa. For Information: Gary Muffy, Gulf Research & Dev. Co., P.O. Drawer, 2038, Pittsburgh 30, Pa. Sponsored By: PGIE: AIEE.
- Oct 5-7 5th National Communications Symposium, Hotel Utica, Utica, New York. For Information: Ralph L. Marks, 126 Glen Road, South Mount Road, Rome, N. Y. Sponsored By: PGCS: Rome-Utica Section.
- Oct 6-8 Conference on Radio Interference Reduction, Museum of Science & Industry, Chicago, Illinois. For Information: S. I. Cohn, Armour Research Foundation, 10 W. 35th Street, Chicago 16, Ill. Sponsored By: PGRFI: Signal Corps, Armour Research Foundation.
- Oct 7-9 IRE Canadian Convention, Toronto, Canada. For Information: D. K. Ritchie, c/o IRE Canadian Convention, 1819 Yonge Street, Toronto 7, Ontario, Canada. Sponsored By: Region 8.
- Oct 12-15 National Electronics Conference, Sherman Hotel, Chicago, Illinois. For Information: Dr. M. E. Van Valkenburg, Electrical Engineering Dept., University of Illinois, Urbana, Illinois. Sponsored By: IRE: AIEE: EIA: SMPTE.
- Oct 19-21 URSI-Fall Meeting, El Cortez Hotel, Balboa Park, San Diego, Calif. For Information: Mrs. Helen E. Hart, Admin. Asst.—URSI U.S. National Committee, 2101 Constitution Avenue, Washington, D. C. Sponsored By: URSI: PGAP, PGCT, PGIT, PGMTT.
- Oct 26-28 East Coast Aero. & Nav. Electronics Conference, Baltimore, Md. For Information: Dr. R. C. Spencer, The Martin Co., Baltimore 3, Md. Sponsored By: PGANE: Baltimore Section ARDC.
- Oct 29-31 Electron Devices Meeting, Shoreham Hotel, Washington, D. C. For Information: Dr. John Hornbeck, Bell Telephone Labs, Murray Hill, N. J. Sponsored By: PGED.

Other Meetings Scheduled:

- Sept 21-25 14th Annual Instrument & Automation Conference, International Amphitheatre, Chicago.
- Oct 6-9 International Symposium on High Temperature Technology, Asilomar Conference Grounds, California. For Information: Stanford Research Institute, Box 734, Menlo Park, Calif.

Oct 11-16 American Society For Testing Materials, Pacific Area National Meeting, Sheraton-Palace Hotel, San Francisco, Calif.

Oct 26-29 Analytical Chemistry, Oak Ridge National Laboratory, Civic Auditorium, Gatlinburg, Tennessee.

NEW DEVELOPMENTS

Halex, Inc., of El Segundo, California, a new corporation pioneering in the field of Molecular Electronics, is specializing in the process of depositing thin films of conductive, semi-conductive and resistive substances to form electronic circuits, according to an announcement made by Harold R. Larsen, President. Halex engineers utilize high vacuum techniques to build up thin films with controlled properties, molecule by molecule, on secondary substances. Thicknesses are readily produced in ranges from less than one millionth of an inch to one hundred millionths of an inch. Through critically controlled processes, specified properties and geometry of almost any material can be achieved. Developments include experimentations with micro-resistors, capacitors, semi-conductors, transducers and micro-sensing devices. Eventually, the firm will concentrate on complete replacement circuits to be used in virtually every kind of electronic device.

Scientists at the Westinghouse research laboratories have taken a major step toward the fast, continuous, completely automatic manufacture of transistors and related semiconductor devices. Dr. S. W. Herwald, vice president-research, disclosed that Westinghouse scientists have constructed long ribbons of semiconductor devices by forming them along the surface of long, thin crystals of germanium about an eighth inch wide and a few thousandths of an inch thick. Such construction appears to be feasible for the automatic production of transistors and other solid state devices directly by machine. In addition to the long experimental strips of devices, hundreds of individual functioning units have been prepared from germanium dendrites by the semiconductor department at Youngwood, Pa.

NEW PLANTS

Amperex Electronic Corporation, Hicksville, Long Island, New York, has announced the beginning of construction of a new, two story, modern, air conditioned engineering wing to the present Amperex building. Amperex is engaged in the development, manufacture and distribution of electron tubes and semiconductors for Government, communications and industry. A tremendous increase in research and development work on highly advanced types of tubes and semiconductors, and the addition of new engineering personnel, has made it necessary to markedly increase facilities, according to Mr. Frank Randall, president. Slated for completion in October 1959, the new engineering wing will add 13,000 square feet of working space to the 100,000 square feet of the present building.

TO OUR SUBSCRIBERS:

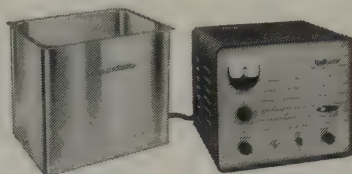
PLEASE ADVISE CIRCULATION DEPT. IMMEDIATELY OF ANY ADDRESS CHANGE. ONE MONTH IS REQUIRED FOR PROCESSING.

MAMMOTH narda SONBLASTER

America's first mass-produced industrial-size ultrasonic cleaner!

SAVE 7 ways over costly solvent, alkaline or vapor degreasing:

- Clean faster, speed production!
- Cut rejects, eliminate bottlenecks!
- Save on chemicals & solvents!
- Eliminate expensive installation!
- Cut maintenance and downtime!
- Save on floor space!
- Release labor for other work!



G-1501 generator, NT-1505 tank.

**MAMMOTH
5-GALLON
TANK
\$695**

Other models from \$175.

2-year guarantee on all units.

SPECIFICATIONS

Interior Tank size (in.), 10W x 14L x 9½H. Tank Capacity, 5 gallons.

Submersible Transducers

Model NT-604 — Hermetically sealed heli-arc welded stainless steel case. Radiating face: 27 sq. in. Effective plane of radiation: 40 to 50 sq. in. (approx. 10" x 5"). Effective cavitation of volumes: up to 1200 cu. in. at 24" tank height (5 gal.) and 2400 cu. in. at 48" tank height (10 gal.). Swagelok tube fitting on side or end for internal tank wiring.

Model NT-605 — Same as NT-604 except for bulkhead fitting on back for external wiring. Eliminates electrical conduits in solutions.

Now you can say goodbye to expensive chemicals, solvents, and degreasing equipment... reclaim valuable floor space... eliminate high installation costs... just by installing a Narda Series 1500 SonBlaster. At the same time, you'll get better, faster cleaning, and you'll need fewer people to do the job!

Get the tremendous activity of the new 200-watt Narda SonBlaster, with the largest transducerized tank ever made, at the lowest price in the industry! Choose from transducerized tanks or submersible transducers for use in any arrangement in any shape tank you desire. Up to 4 submersible transducers can be easily operated from the same generator at one time; load selector switch provided — an exclusive Narda feature.

Simply plug the SonBlaster into any 110-115 V AC line, and flip the switch. In seconds, you'll clean 'most any mechanical, optical, electrical, medical or horological part or assembly you can think of. Perfect, too, for brightening, polishing, radioactive decontaminating, pickling, quenching and plating; emulsifying, mixing, sterilizing, impregnating, degassing, and other chemical process applications.

Mail the coupon for free help in determining the model that's best for you.

The SonBlaster catalog line of ultrasonic cleaning equipment ranges from 35 watts to 2.5 KW, and includes transducerized tanks as well as immersible transducers. If ultrasonics can be applied to help improve your process, Narda will recommend the finest, most dependable equipment available — and at the lowest price in the industry!

The Narda Ultrasonics Corporation
625 Main Street
Westbury, L. I., N. Y.
Department SP-6

Gentlemen:

Please send me more information about

- ☐ Series 1500 SonBlasters
- ☐ The complete Narda line

Name _____

Organization _____

Address _____

City _____

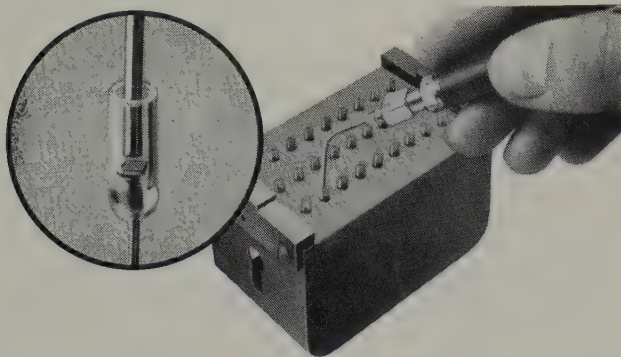
Zone _____ State _____



the narda ultrasonics corporation
625 MAIN STREET, WESTBURY, L. I., N. Y.
Subsidiary of The Narda Microwave Corporation

Circle No. 26 on Reader Service Card

**NOW – Handle tiny parts
the easy, fast, accurate way, with . . .**



the CARMAN VACUUM PENCIL SYSTEM

Ideal for delicate operations easily damaged by tweezers or other handling devices. A foot operated switch allows the operator to release the suction when the part is correctly positioned. Included are inter-changeable tips and all necessary tubing, connectors and parts. Needs only a vacuum source (supplied as an accessory) and 115 V, 60 Cycle power.

Single station units \$89.50 (Approx.)

Carman Labs manufacture special purpose production equipment for the semiconductor industry. Please write for additional literature and information.

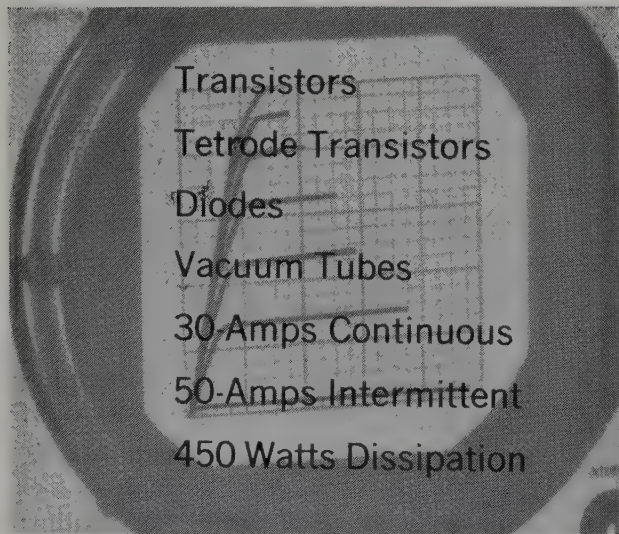


CARMAN LABORATORIES, INC.

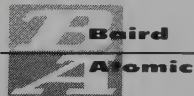
1013 CARMAN ROAD, BEDFORD, MASS.

Circle No. 27 on Reader Service Card

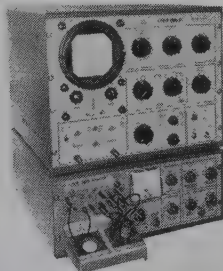
NEW CURVE TRACER with Tube Adapter



For complete information
write for bulletin #TT108.



Baird-Atomic, Inc.
33 UNIVERSITY RD.,
CAMBRIDGE 38, MASS.



Circle No. 28 on Reader Service Card

MARKET NEWS . .

Financial

Clevite Corp., sales and profits have reached an all time high during the first six months of 1959. It has reported a earning per share of \$1.78 as compared with 59¢ during the first half of 1958. The semiconductor volume of the company was reported to be almost twice that of a year ago. A \$10 million semiconductor plant is to be constructed shortly in Waltham, Mass.

Daystrom Inc., net in the first fiscal quarter ended June 30 climbed to approximately 40¢ per share as compared with 18¢ a share for the same period last year. Sales increased some 18% to a first quarter record of \$21,250,000 over last year's initial quarter.

International Resistance Co., has reported a 61 percent rise in first-half-year sales over the same period in 1958 and earnings of 67.7 cents per share. International Resistance Company had sales of \$9,409,128 for the 25 weeks ended June 22, 1959 as against sales of \$5,846,958 in the comparable period of 1958. Earnings for the half year of \$927,601 contrasted with a loss of \$71,248 in 1958.

For its first fiscal quarter (ended May 31, 1959) General Instrument Corporation new profits increased approximately 130% over the same period last year and sales rose 46% to the highest level for any first quarter in the Company's 366 year history. General Instrument sales for the first three months of fiscal 1959-60 totalled \$12,728,861 as compared with \$8,679,027 for the same period last year. Net earnings were \$211,129 or 14¢ per share (on 1,497,723 shares outstanding) more than double the \$87,916 or 6¢ per share earned in last year's first quarter period. The first quarter gains were mainly due to rising sales of: semi-conductors (first quarter shipments and backlog were approximately three times those of last year's first quarter); military equipment; TV-radio components.

Industro Transistor Corp., Long Island City, N.Y., recently sold an offering of 100,000 common shares at \$5.50 per share.

Stockholders of General Transistor Corp., N.Y., have approved a two-for-one split of its common stock and an increase in the authorized stock from 750,000 to 2 million shares.

The expected split in the share of Texas Instruments Inc. has been postponed by the directors of the company, who felt that, "It is in the best interests of the company and its stockholders not to consider the matter of a split at this time." The values of the shares have been moving up sharply recently.

Estimated net earnings for Motorola Inc., for the second quarter ending June 30th are expected to be about \$3,090,000 or about \$1.58 per share as compared with \$800,515 or 41¢ a share a year ago. Sales for the second quarter are about \$65,300,000 as compared with \$43,650,070 for the same period last year.

Rheem Manufacturing Company has sold its Defense and Technical Products division "Rel" proprietary line in Downey, Cal. Rheem will continue to engage in the development and manufacture of electronics equipment through its Electronics division in South Gate, Cal., and its four-months-old Rheem Semiconductor Corp. in Mountain View, Cal.

U.S. Semiconductor Products, Inc., of Phoenix, has purchased the adjacent building for \$270,000 which formerly was the plant of the U.S. Electronics Development Corp.

A new firm, National Semiconductor Corp. has been established in Danbury, Conn.

Agreement has been reached in negotiations by Telechrome Manufacturing Co. to acquire control of Universal Transistor Products Corp., Westbury, N.Y. Universal has been operating under a court appointed receivership since last February.

Radio Corporation of America's first half earnings for 1959 are \$19,400,000 (\$1.29 per share). This represents 44% above the sum netted in the first half of 1958. Sales rose to a new record of \$633,700,000 in the latest half as compared to \$542,600,000 of a year ago.

Contracts Awarded

General Electric Co., Syracuse, N.Y., \$75,000 contract #78346. Research and development for 18 months leading to the establishment of designs for solid-state reciprocal and non-reciprocal filters.

Sylvania Electric Products, Inc., Woburn, Mass. \$34,662 contract #84765, 3,180 semiconductor device diodes.

Electromechanical Instrument Division, Consolidated Electro-dynamics Corp., received an order from Graybar Electric Co., of \$400,000 for transistorized portable test instruments to be used by the Federal Aviation Agency in its air traffic control system.

Transitron Electronic Corp., Wakefield, Mass., \$222,111 contract #81286, industrial preparedness measure on transistors.

Servo Corp. of America, New Hyde Park, N.Y. \$146,000 contract #81288, industrial preparedness measure for thermistor bolometer detectors.

The U.S. Army Engineers Research and Development Laboratories has granted \$45,000 to Colorado State University to continue a three year research program on properties of thin films of metals, semiconductors and insulators.

The Army Signal Corps has awarded to the Radio Corporation of America, Camden, N.J. an additional contract for \$2,388,000 for the production system phase of the micro-module program. Under this program the vast range of jobs performed by transistors and other electronic parts is being compressed into circuit building blocks measuring only a third-of-an-inch on either side.

Transitron Electronic Corp., Wakefield, Mass. \$21,900 for 10,000 items of diodes type 1N-457, IFB-1079.

Western Electric Co., Inc., N.Y. \$93,428 contract #84733; 18,268 semiconductor device diodes.

Microwave Assoc., Inc., Burlington, Mass. \$6,200.90 for 2,102 semiconductors ORD-01-021-50-10618.

The Siegler Corporation has been awarded a \$100,000 contract from the Sperry Utah Engineering Company, a subsidiary of Sperry-Rand Corporation, for the manufacture of special electronic test gear for the Army's "Sergeant" missile. These units are completely transistorized and miniaturized in aluminum castings, only one-fifth the size of previously available equipment which performed similar testing programs.

Industro Transistor Corp., of Long Island City has doubled its direct labor personnel in the last three months. The company is currently fulfilling a \$200,000 subcontract from General Electric Co., for high frequency PNP germanium transistors.

Digital Equipment Corp., Maynard, Mass. transistorized modules (IFB 19-604-59-206) \$25,646.00.

Suppliers

American Smelting and Refining Company has installed new facilities at its Perth Amboy, New Jersey, plant which will increase its capacity to produce high purity (99.999%) indium. Asarco has produced high purity indium at its Central Research Laboratories in South Plainfield, N.J., for the past 5 years. Increasing demand for the metal in electronic applications necessitated the completion of larger facilities for the production of commercial quantities.

3100°F element temperature

KANTHAL SUPER

Unique molybdenum disilicide furnace elements outlast silicon carbide at least four to one above 2700°F, saving substantially on down-time. For continuous or intermittent operation in oxidizing and most protective atmospheres. Elements operate to 3100°F (1700°C) when freely suspended or to 2900°F (1600°C) when supported horizontally.

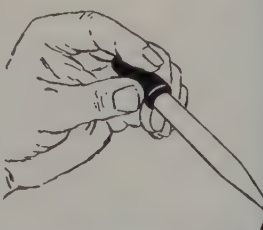
Kanthal Super does not age, and temperatures can be held without compensating adjustments.

Kanthal Super elements are available separately and in furnaces from all prominent manufacturers. Write for list and brochure today.

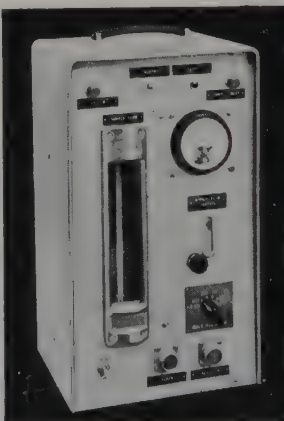


THE KANTHAL CORPORATION
19 Amelia Pl., Stamford, Conn.
Can. Rep. Ferro Enamels, Ont., Can.

Circle No. 29 on Reader Service Card



Measures water content better than 1 part per 1,000,000!



MODEL W ELECTROLYTIC
MOISTURE ANALYZER
Vacuum connected unit with
adjustable alarm

Useful applications:

- Analyzing "Freon" and Sulfur Dioxide refrigerants.
- Continuous or batch analyses of moisture in a wide variety of gas streams — including process streams, inert atmospheres required in plant processes and laboratory dry boxes, and plant instrument streams.
- Measuring reaction rates where water is involved as a reactant, product or catalyst.

Available in portable, weather-proof, explosion-proof, automatic control and recording units.

All Model W analyzers include flow indicators
Write for complete information

**MANUFACTURERS ENGINEERING
& EQUIPMENT CORP.**

10 Sunset Lane, Hatboro, Pa.

MEECO
Instruments

Circle No. 30 on Reader Service Card



COLUMBUS ELECTRONICS CORP.

DOUBLE DIFFUSED SILICON RECTIFIERS



Now... an extensive line of high performance, hermetically sealed, silicon power rectifiers UP TO 35 AMPS. JEDEC types exceeding MIL specifications.

NEW

SINGLE unit VERY HIGH VOLTAGE silicon rectifiers exhibiting these desirable characteristics...

HIGH
VOLTAGE
up to 2000 PIV

LOW
FORWARD DROP
1.5 Volts, DC

EXTREMELY
LOW LEAKAGE
1 μ A

FORWARD
CURRENT
up to 20 Amps.

NEW

INSULATED STUD silicon rectifiers offering these quality features...

- Simplify mounting
- Saves assembly parts & costs
- Obtain efficient heat transfer
- Give greater design flexibility

AVAILABLE UP TO 10 AMPS PER UNIT AND UP TO 2000 VOLTS PIV.

WRITE FOR FULL DETAILS

COLUMBUS ELECTRONICS CORP.
1010 SAW MILL RIVER RD., YONKERS, N. Y.
YOnkers 8-1221 • TWX-Yonkers, NY-1369

Circle No. 31 on Reader Service Card

[from page 17]

ion at the input and output ports, the transducer gain will be a maximum and is given by the expression:

$$G_{T \text{ max. neutralized}} = \frac{(y_{21} - y_{12})^2}{4(g_{11} + g_{12})(g_{22} + g_{12})}$$

where g_{11} = Real part of y_{11}

g_{22} = Real part of y_{22}

g_s = Source conductance

g_L = Load conductance

Circle 200 on Reader Service Card

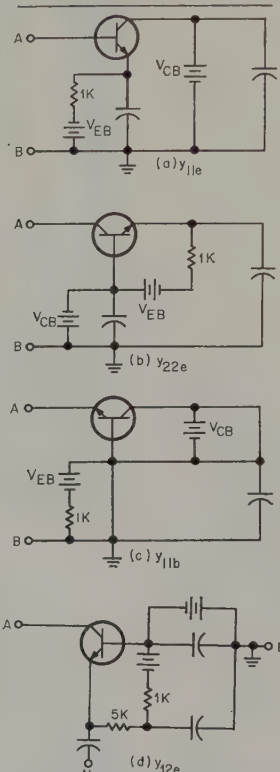


Fig. 15.2—Circuits for measuring the "y" parameters.

Super-Sub-Miniature Transformers

For transistor circuitry
in servo-mechanisms, hearing
aids, radios, telephones



- High reliability guaranteed.
- Large quantities used, with transistors, by leading manufacturers.
- Some of the most Important prototypes in use today are:

Type	H	W	D
M-200	.237	.340	.280
F-2010	.263	.410	.325
AAT-408	.307	.376	.325
SM-400	.400	.563	.485
NA-2350	.750	1	.750
GEN-2020	1 1/16"	1 1/4"	7/8"

- Immediate delivery from inventory covering wide range of impedance ratios in sub-miniature and super-sub-miniature sizes.
- Prototypes—Designed or wound and enclosed to specifications. . . . Delivery within two weeks.

For further information and catalog call or write today . . .

Frank Kessler Co., Inc., 41-45 47th St.
L.I.C. 4, N.Y. • Tel.: Stillwell 4-0263

Circle No. 32 on Reader Service Card

REPRESENTATIVES WANTED

Eastern manufacturer of equipment for the semiconductor industry is seeking mid-West and West Coast representation. Sales, engineering service and repeat orders of expendable items is involved.

RW-2254, Electronics
Class. Adv. Div., P.O. Box 12, N.Y. 36, N.Y.

Packs A Lot Of Capacity Into A Little Space

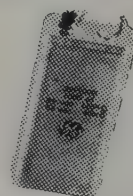


NEW KSR* TANTALYTIC® CAPACITORS

For Example: 3500
MFD at 15 volts.
Size 1.31" x .75" x
2.5" high.

Send for Special GE Guide

*Registered Trade-mark of General Electric Co.



The new designs provide up to 40% reduction in weight, and 30% reduction in required space, when compared to other foil tantalum units. They also cost less per volt-microfarad.

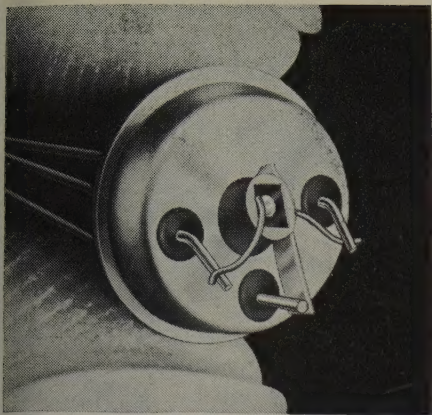


Schweber

ELECTRONICS

60 HERRICKS ROAD, MINEOLA, L. I., N. Y. PIONEER 6-6520. TWX G-CY-NY-580 U

Circle No. 33 on Reader Service Card



PERSONNEL NOTES

Dr. David M. Heinz has been appointed a senior scientist at Hoffman Electronics Corporation's Science Center in Santa Barbara, Calif. Dr. Heinz, as part of a scientific group engaged in research involving new electronic devices and systems, will concentrate on semiconductor materials and in the field of general chemistry. A member of the American Physical Society and Electro-Chemical Society, he holds a B.S. degree in chemistry from the University of Pittsburgh and an M.S. in chemistry from Columbia University. He received his Ph.D. in Inorganic Physical Chemistry in 1954 from the Polytechnic Institute of Brooklyn where his thesis was on the growth of large single crystals of cadmium selenide and related compounds.

E. O. Vetter, an Assistant Vice President since 1958, has been elected a Vice President of Texas Instruments Incorporated effective August 1. Mr. Vetter also assumed, on September 1, the position of division manager of Metals & Controls division of Texas Instruments in Attleboro, Massachusetts, where he has been assigned for the past several months as general manager. He is a graduate of Massachusetts Institute of Technology, a member of the Institute of Radio Engineers and the Instrument Society of America.

Mr. Edward L. Badwick, formerly Production Engineer with Bendix Aviation Corp., Semiconductor Division at Long Branch, New Jersey, has been appointed Plant Manager of Accurate Specialties Co., Inc. new semiconductor component facility at 338 Hudson Street, Hackensack, New Jersey. A graduate of Polytechnic Institute of Brooklyn, he also received his Master's Degree in Metallurgy at Stevens Institute of Technology. He is a member of the American Society of Metals, and the American Institute of Mining and Metallurgical Engineers.

Allegheny Electronic Chemicals Co., recently announced three managerial appointments. Lloyd E. Mount has been appointed manager of the Custom Processing plant. He will be responsible for all single crystal processing of semiconductor materials. Robert J. Stewart has been appointed production manager of Allegheny's Bulk Chemical plant, which currently produces polycrystalline silicon. Edward Sailer has been appointed manager of the Materials Laboratory. He will be responsible for materials evaluation, quality control and customer services.

Arne Christensen has joined the Semiconductor Division of Sylvania Electric Products Inc., as a sales engineer at the company's sales office at Melrose Park, Ill., it has been announced by Ernest H. Ulm, division general sales manager. Mr. Christensen will call upon manufacturers of electronic equipment in the states of Illinois, Wisconsin and Minnesota. He will be responsible for Sylvania's full line of transistors, diodes and rectifiers.

how to CUT COSTS on small components

If the cost of metal stampings and wire forms figures in your profit picture, let us give you a quotation on your current components. Send us a sample or blueprint... and discover how big savings in time and production costs, big gains in precision and uniformity are possible on small components, when Art Wire tackles the job!

Our engineering staff, our production experience, and our modern high speed equipment are always at your disposal. If you wish to learn more about what a wide and versatile range of shapes and parts we can produce for you—at lower cost than you'd guess—just write for our illustrated folder.

ART WIRE AND STAMPING CO.

29 Boyden Place, Newark 2, N. J.
Circle No. 35 on Reader Service Card

Why semiconductor yield increases ...with ALPHA UHP ultra high purity dot materials

Conformity to dot dimension and weight requirements greatly affects alloy junction semiconductor yield.

To insure conformity, ALPHA UHP* ultra high purity dot materials are subjected to the following controls:

1. Rolling. Using elements as refined as 99.999+ purity, ALPHA rolls the specified metal to the required dimension.

During rolling, continual checks are made with precision gauges. Constant and uniform thickness results: *conformity to dimensional and weight requirements is assured!*

2. Punching. ALPHA dot materials are fabricated with special punches and dies. Specially designed, they control dot accuracy. Carefully inspected before using, these punches and dies are reworked as necessary. This keeps them in perfect order, further safeguards the conformity of ALPHA dot materials to your specifications!

3. Spherizing. Exact classification techniques and equipment unique with ALPHA metals help produce spheres whose dimensional accuracy is as close as $\pm .0002"$. In certain sizes, accuracy of $\pm .0001"$ is attained. *Sensitive balances and precision gauges safeguard dimensional consistency!*

Throughout the fabricating cycle, ALPHA dot materials' conformity to dimensional and weight requirements is maintained. Dot uniformity controls penetration, produces uniform junctions. *You gain increased semiconductor yield!*

FREE! Learn how ALPHA dot materials' other properties, too, increase your semiconductor yield. For informative technical data, write today.



ALPHA METALS, INC.

57A WATER ST., JERSEY CITY 4, N. J.
Henderson 4-6778

In Chicago, Ill.

ALPHA-LOY CORP. (Division of Alpha Metals)
2250 S. Lumber St., Chicago 16, Ill. MOntrope 6-5280

Other ALPHA Products... Core & Solid Wire Solder
Wide Range of Fluxes... Soft Solder Preforms

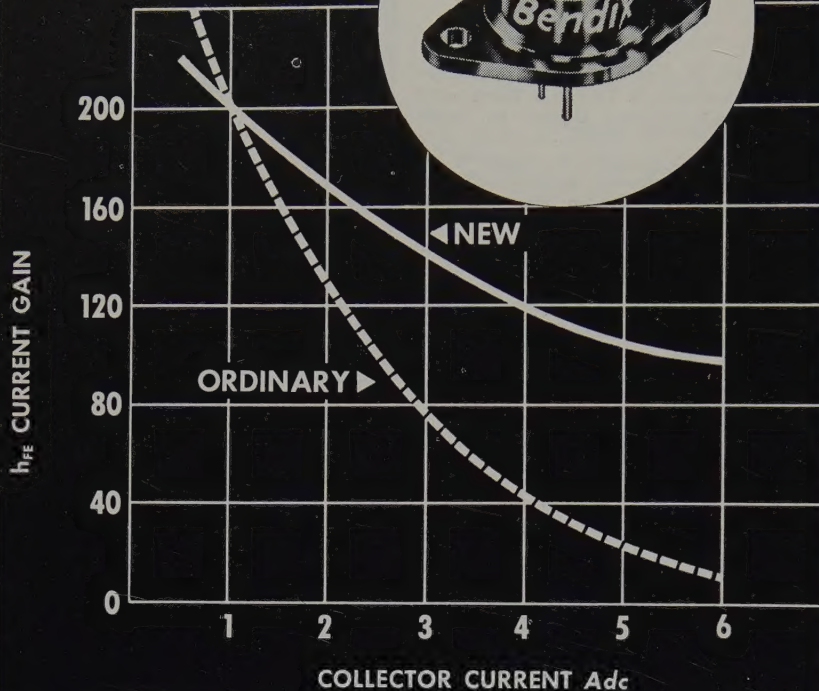
*Trademark

Circle No. 34 on Reader Service Card

SEMICONDUCTOR PRODUCTS • SEPTEMBER 1959

Index to Advertisers

Aeroprojects, Inc.	55
Allegheny Electronic Chemical Co.	16
Allied Chemical Corp. General Chemical Div.	12
Alpha Metals, Inc.	63
Art Wire & Stamping Co.	63
Baird-Atomic Inc.	60
Bendix Aviation Corp.	64
Birtcher Corporation, The	51
Carman Laboratories Inc.	60
Cohn, Sigmund, Corp.	53
Columbus Electronics	62
Electronic Laboratory Supply Co.	52
Electronic Measurements Co., Inc.	10
Elinex	52
Epoxy Products, Inc.	1, 39
Fairchild Semiconductor Corp. ...	6, 7
General Electric Co. Semiconductor Products Dept.	57
Hughes Aircraft Co. Semiconductor Division	13
Indium Corp. of America, The ..	58
Kahle Engineering Co.	8
Kanthal Corp., The	61
Kessler, Frank Co., Inc.	62
Knapic Electro-Physics, Inc.	18
Lepel High Frequency Labs., Inc.	50
Manufacturers Engineering & Equipment Corp.,	61
Merck & Co., Inc.	5
Micromech Manufacturing Corp.	51, 62
Milgray	Covers IIA & IIB
Missile Manual and Guide	4
Narda Ultrasonics Corp.	59
North Hills Electric Co., Inc.	52
Philco Corporation Lansdale Tube Co., Div.	49
Radio Corporation of America	15, 54
Radio Receptor Company, Inc. ...	17
Raytheon Co., Semiconductor Division	2
Sarkes-Tarzian, Inc.	Cover III
Schweber Electronics	62
Sprague Electric Co.	Cover IV
Texas Instruments Incorporated Cover II,	19
Trancoa Chemical Corporation ..	11
United Carbon Prods. Co., Inc. ...	20



Solid line indicates the low beta fall-off of one of the new Bendix transistors as compared to that of an ordinary transistor.

NEW BENDIX HIGH GAIN INDUSTRIAL POWER TRANSISTORS OFFER FLATTEST BETA CURVE

Now available—a new series of power transistors with the flattest beta curve in the industry, made possible by an exclusive Bendix process. This new series has very high current gains—up to 200 at 3 Adc—and a 10 ampere peak current rating.

Featuring ten-amp performance at a five-amp price, the 2N1136,A,B; 2N1137,A,B; and 2N1138,A,B series provide:

LOW BETA FALL-OFF	→	LESS DRIVE AND LESS DISTORTION
LOW SATURATION RESISTANCE	→	GREATER CIRCUIT EFFICIENCY
VOLTAGE BREAKDOWN RATINGS	→	ELIMINATION OF BURN-OUT
CURRENT GAIN MATCHING	→	OPTIMUM CIRCUIT PERFORMANCE

Ideally suited for use in static converters and regulators, these powerful transistors also have numerous applications in relay replacements and drivers for relays, magnetic clutches, solenoids and other loads requiring high current. In addition, their extremely high current gain and excellent hFE linearity make them the most practical and efficient television vertical output amplifiers.

For complete information, contact SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, NEW JERSEY.

West Coast Sales Office: 117 E. Providencia Avenue, Burbank, California

Midwest Sales Office: 4104 N. Harlem Avenue, Chicago 34, Illinois

New England Sales Office: 4 Lloyd Road, Tewksbury, Massachusetts

Export Sales Office: Bendix International Division, 205 E. 42nd Street, New York 17, New York

Canadian Affiliate: Computing Devices of Canada, Ltd., P. O. Box 508, Ottawa 4, Ontario, Canada.

Red Bank Division



Circle No. 36 on Reader Service Card

from 150 milliamperes to 250 amperes

Tarzian

complete line of
SILICON RECTIFIERS

*Over 190
standard types
from which
to choose*

Peak inverse voltages from
50 to 400 volts in most
types—as high as 600 in
many. Positive or negative
base polarity available
in all models rated
at 20 amperes and over.

Complete engineering service
and recommendations available.

Send for catalog.

SARKES TARZIAN, INC., RECTIFIER DIVISION, DEPT. SP5
415 NORTH COLLEGE AVE., BLOOMINGTON, INDIANA

In Canada: 700 Weston Rd., Toronto 9. Tel. Roger 2-7535

Export: Ad Auriema, Inc., New York City

Circle No. 2 on Reader Service Card



micro-alloy transistors from **SPRAGUE***

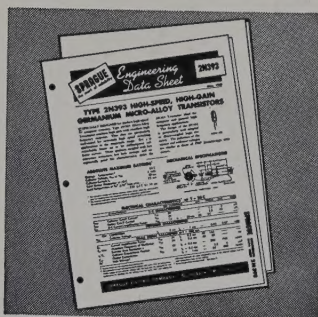
2N393



HIGH-SPEED, HIGH-GAIN MICRO-ALLOY TRANSISTORS
for modern digital computer circuitry

TYPE 2N393 Micro-Alloy Transistors combine high gain with excellent high frequency response to meet the demands of high-speed computer switching applications in the megacycle range. Low saturation resistance, low hole storage, and exceptionally good life characteristics make these transistors top performers in computer circuits as well as in general high-frequency applications.

D-C β is remarkably linear up to 50 milliamperes collector current. The design of the 2N393 is particularly well adapted to direct-coupled logic circuitry. The polarities of the emitter and collector voltages are similar to those of PNP junction-type transistors.



Made by electrochemical manufacturing techniques, Sprague Micro-Alloy Transistors are uniformly reliable and very reasonably priced.

Write for complete engineering data sheets to Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

***** *Sprague Type 2N393 micro-alloy transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type numbers are manufactured to the same specifications and are fully interchangeable. You have two sources of supply when you use Sprague transistors!*



2N393

	Min.	Typ.
h_{FE}	20	95
f_{max}	40	60

SPRAGUE COMPONENTS:

TRANSISTORS • RESISTORS • MAGNETIC COMPONENTS
CAPACITORS • INTERFERENCE FILTERS • PULSE NETWORKS
HIGH TEMPERATURE MAGNET WIRE • CERAMIC-BASE PRINTED
NETWORKS • PACKAGED COMPONENT ASSEMBLIES

SPRAGUE®
THE MARK OF RELIABILITY

Circle No. 3 on Reader Service Card

